Quality assurance of continuous emission measuring system (CEMS) (practical example)

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Summary / Overview

Quality assurance of CEMS according to EN 14181 with practical examples

- QAL1 (type testing)
- Choice of CEM / measurement section
- QAL2 (calibration)
- QAL3 (ongoing QA)
- AST (including functional test)
- CEM Data Management in Germany

Timescale of Quality assurance (QA) for CEMS

QAL1

- <u>type test of AMS :</u>
  manufacturer of AMS orders a test lab
  after check of official sites the manufacturer gets a certificate for the AMS

During planning

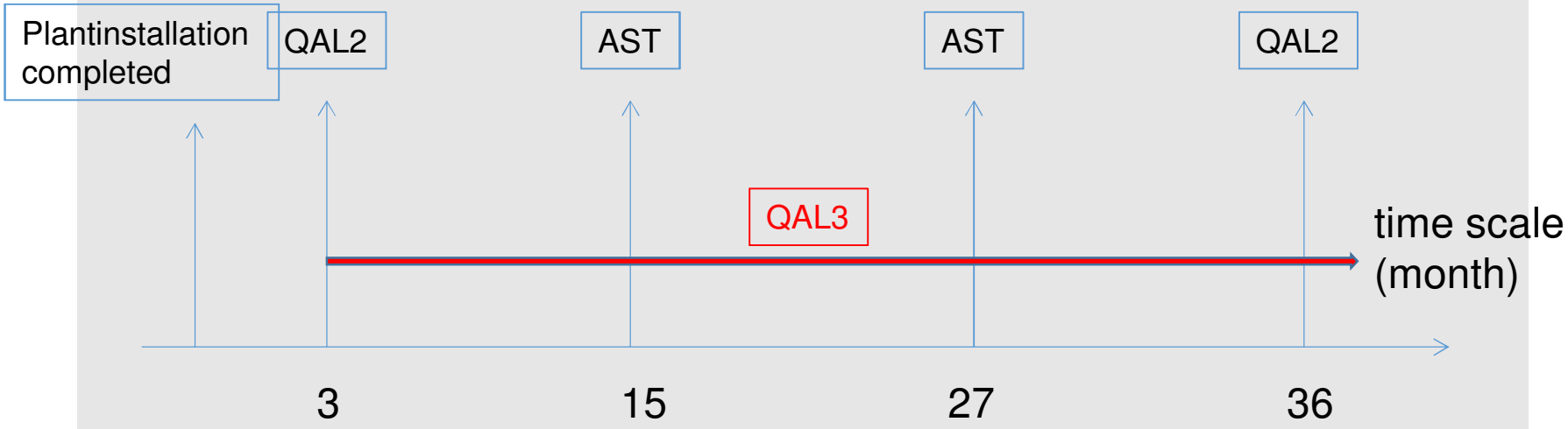
- <u>During planning of a new plant :</u>
  measurement site, type CEMS to use has to be fixed

After Installation

- <u>After installation of the plant :</u>
  (with a suitable measurement site and CEMS)
  a first check of the CEMS is performed.
  (at the end in Germany: certificate of proper installation)

Timescale of QA for CEMS

- After 3 months (max. 6 months) the QAL2 is performed.
- Afterwards an AST has to be done yearly
- After 3 years the next QAL2 has to be performed



Concrete Example (1)

- **Powerplant:**
  capacity of the power station: 80 MW
  type of fuel: coal
- **Components to measure:**
  CO, NO_x and O_2 (reference oxygen content) and reference values (T, p, humidity)
- **ELV and AMS-uncertainty for:**
  CO: 150 mg/m³ ; 7,5 % (EN 15267-3)
  NO_x: 300 mg/m³ ; 15 % (EN 15267-3)
  reference oxygen: 6 Vol% (273 K, 1013 hPa, dry)

Baseline ranges, ELVs and uncertainties

Table 2 – Baseline ranges, ELVs and uncertainties

	ELV, $mg.m^{-3}$	Certification range, $mg.m^{-3}$	Allowable uncertainty, %	Allowable uncertainty, $mg.m^{-3}$
NOx – incineration	200	300	20%	40
NOx – large combustion plant, solid/liquid fuel	200 - 600	500 - 1500	20%	40 – 120
NOx – large combustion plant, gaseous fuels	200 - 300	500 - 750	20%	40 – 60
NOx – large combustion plant, gas turbines	50 - 120	125 - 300	20%	10 – 24
SO_2 – large combustion plant, solid/liquid fuel	200 - 850	500 - 2125	20%	40 – 170
SO_2 – large combustion plant, gaseous fuels	35-800	88 - 2000	20%	7 – 160
SO_2 – incineration	50	75	20%	10
CO – incineration	50	75	10% (20%)	5 (10)
HCl – incineration	10	15	40%	4
Particulate matter, large combustion plant	30 - 50	75 - 125	30%	9 - 15
Particulate matter, incineration	10	15	30%	3
Particulate matter, co-incineration	30	45	30%	9
Total organic carbon, incineration	10	15	30%	3

Note 1: NOx is expressed as NO_2. Therefore if a CEM measures NO alone, then the measurement must be converted to a NO_2 equivalent. For example, if the range for NO is 0 to 100 $mg.m^{-3}$, then the range for an NO_2 equivalent (or total NOx) will be 0 to 153 $mg.m^{-3}$.

Requirements for the CEMS:

- Certified according to QAL1 of the EN 14181
  (certification standard EN 15267-3)
- Suitable for plant type: combustion plant
- Certified range suitable for the ELV of the plant
  certified range about 1,5 *ELV (incineration process) or
  2,5 *ELV (large combustion plant)
- Certification range (CR) versus
  measurement range (MR)
  MR = in this range the CEMS can measure
  CR = the smallest range that meets the performance
  standards according to QAL1

Requirements for the CEMS:

- In-Situ vs. out stack

Advantage:

out stack: exhaust matrix effects can be solved (water droplets, dust)
In-Situ: maintenance easier, no problems with sampling (changing pressure)

Disadvantage:

in-situ: reference components needed
out-stack: loss in the sampling system

CEMS for Nitrogenoxides (NO_x)

Limit value for Nitrogenoxide expressed as NO_2

a) Measuring total NO_x ($NO + NO_2$) e. g. for gasturbine plants necessary

b) Measuring NO alone (if NO_2-portion < 5%) acquisition of additional NO_2 -content by calibration
usually in combustion plants

Selection of suitable AMS

- Web-sources

  Germany: TÜV Rheinland (QAL1.de)
  Great Britain: MCERTS
  (http://www.csagroupuk.org/services/mcerts/mcerts-product-certification/mcerts-certified-products/)

- Example MCERTS:
  ENDA-500 (Horiba)
  (http://www.csagroupuk.org/wp-content/uploads/2015/05/MC12021200.pdf)

- Example QAL1.de:
  MGA12 (Födisch)
  (http://www.qal1.de/15267/0000039321_00_foedisch_MGA12_en.pdf)

Information of a certificate

- Certification range (the lowest range)
  e. g. ENDA-500 (Horiba)
  for NO: 0 to 100 mg/m³and for CO: 0 to 50 mg/m³
- Restrictions
  (not fulfilled requirements of performance data)
  e.g. MGA12 (Födisch):
  - The ambient temperature must not exceed +30 °C.
  - The performance criterion as related to the expanded uncertainty according to EN 15267-3 was not fulfilled for the component CO.

Information of a certificate

- Approved site application
- Basis of certification (test report)
- Description of the certified system in detail

  e.g. MGA12 (Födisch):
  extractive system
  with a IR analyzer for CO, NO, SO_2 and CO_2; electrochemical cell for O_2
  sample gas probe (HSP 12),
  heated sample gas pipe (25m) and
  gas cooler (GCU 12)

Information of a certificate

- Certified performance
  (in MCERTS-certificate measured data versus requirements are listed; in qal1.de-certificate only the measurement uncertainty) e.g.
  - response time
  - repeatability at zero and reference point
  - lack of fit
  - measurement uncertainty
  - influence of ambient temperature, variation of the gasflow, voltage variation
  - cross sensitivity

Cross sensitivity / cross interference

- Tested components:
  Oxygen, humidity, CO_2, CH_4, N_2O, NO, NO_2, NH_3, SO_2, HCl
- For CO (MGA12) relevant:
  Oxygen, humidity, CO_2, N_2O, SO_2
- This cross sensitivity for the relevant compounds should be tested in functional test

Concrete Example (2)

- Choice of the CEMS
  ENDA-500 seems to be better suitable than MGA12, because of the restrictions of the MGA12 (ambient temperature and measurement uncertainty for CO)
- Installation of the AMS
  - Right position (EN 15259)
    representative sampling possible
    homogenous flow conditions
    (5 hydraulic diameters of straight duct upstream and
    2 hydraulic diameters of straight duct upstream
    of the sampling)

Key

1 measurement point

2 measurement line

3 measurement plane

4 measurement port

5 clearance area

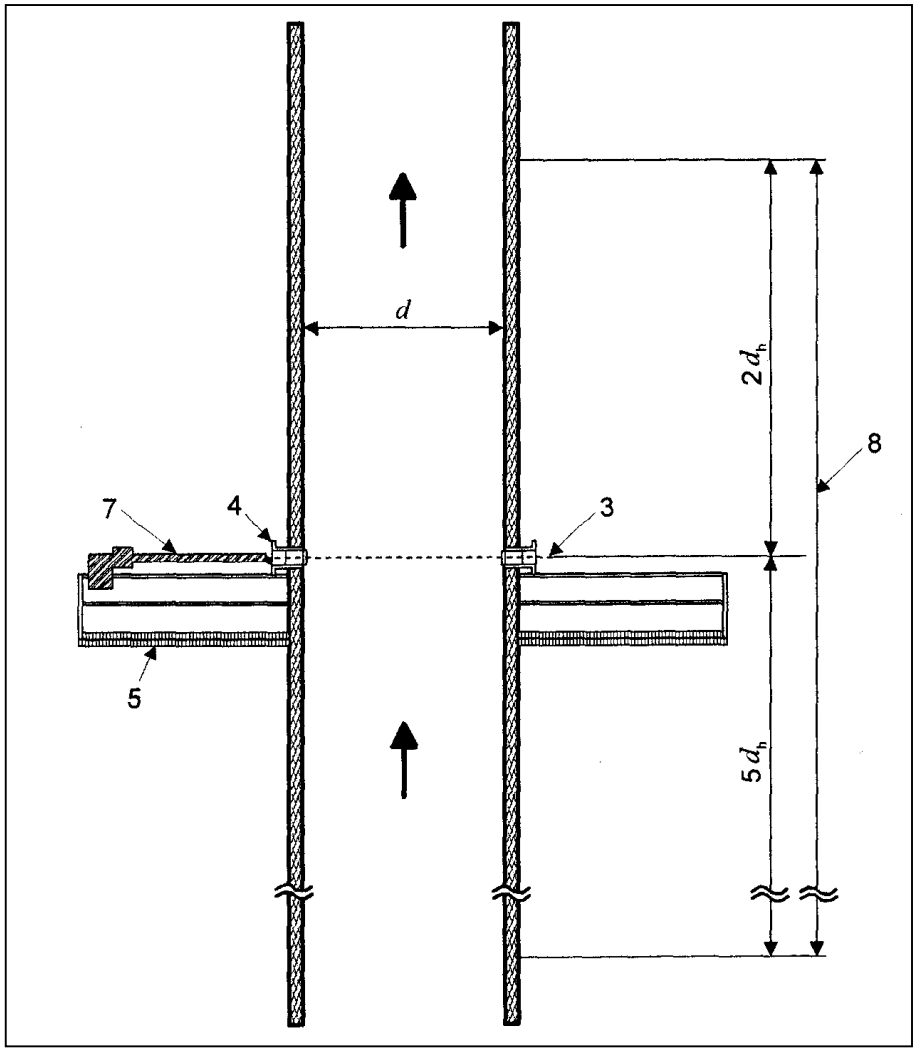
6 measurement site

7 manual sampling train

Symbols

d internal stack diameter

d_h hydraulic diameter



Concrete Example (2)

- Requirements for the installation site regarding the execution of the Standard Reference Measurements (SRM)
  - Sufficient space for the working area and space (minimum 4 m² for simple measurement tasks)
  - Power supply and equipment power connection sufficient
  - Safety and environmental conditions easily and safety accessible via stairs, equipment for transportation
  - Suitable measurement ports

Key

1 measurement point

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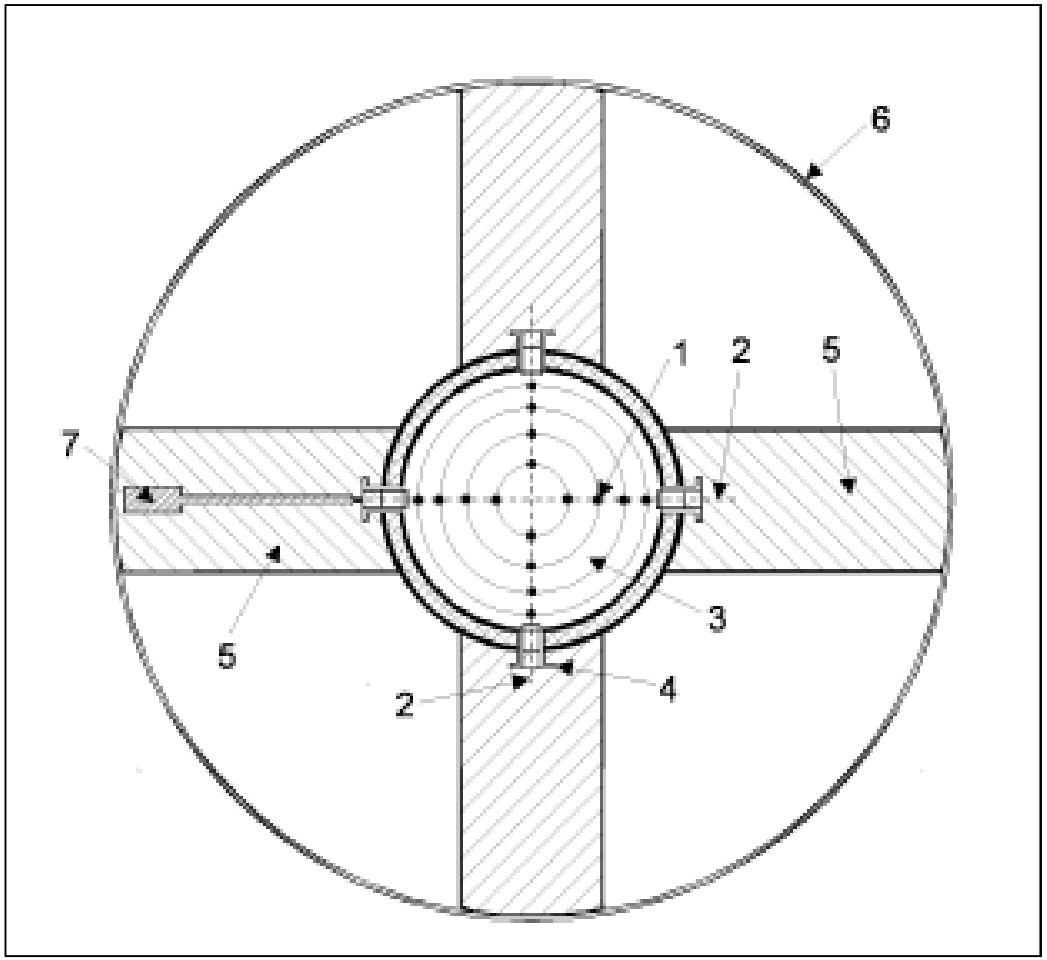
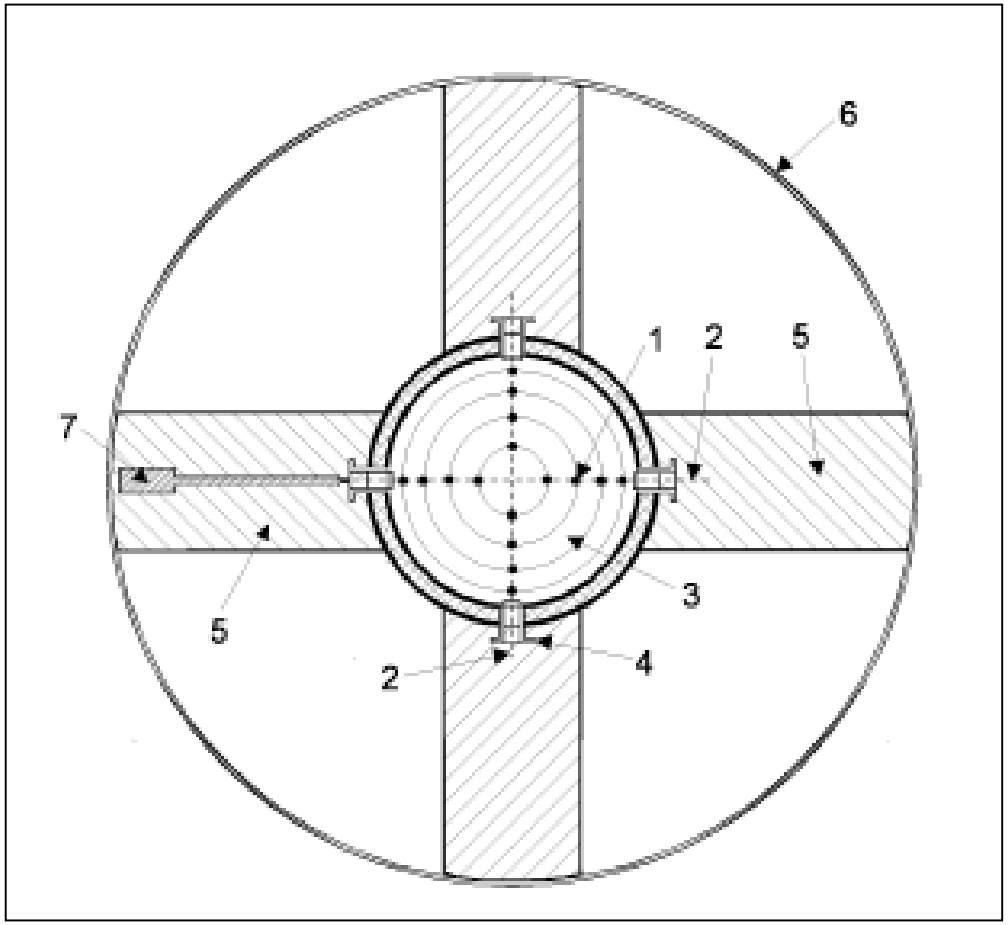


Check of the homogeneity at the measurement plane according to EN 15259 (8.4)

Need of two AMS

One at a fixed point in the measurement section

one for a grid measurement



Finding the best available measurement point in the measurement plane for the AMS

Industrial Site:	Powerplant
Emission Source:	
Date :	

Axis - depth	NO_x		Oxygen content		Temperature		Velocity			Info profile 1
	c_{grid} mg/m³	c_{ref} mg/m³	o_{grid} %	o_{ref} %	T_{grid} °C	T_{ref} °C	v_{grid} m/s	v_{ref} m/s	F_{rep} %	abs (deviation)
Axis 1 - 0,16 m	516,0	492,0	7,8	8,6	362	346	27,2	20,3	126,2%	0,12
Axis 1 - 0,47 m	542,0	501,0	7,6	8,7	373	346	28,9	20,5	129,9%	0,16
Axis 1 - 0,78 m	540,0	499,0	7,9	8,8	380	346	29,3	19,9	135,1%	0,21
Axis 1 - 1,09 m	554,0	504,0	7,9	8,8	376	346	30,3	23,1	123,6%	0,10
Axis 2 - 0,16 m	429,0	493,0	10,5	8,9	343	346	16,9	19,6	87,2%	0,26
Axis 2 - 0,47 m	497,0	489,0	8,6	8,8	355	344	29,0	19,5	144,1%	0,30
Axis 2 - 0,78 m	505,0	486,0	8,3	8,8	373	344	30,3	20,5	136,1%	0,22
Axis 2 - 1,09 m	480,0	463,0	8,3	8,7	364	344	27,1	20,5	125,4%	0,12
Axis 3 - 0,16 m	440,0	468,0	9,4	8,7	332	342	5,7	20,3	28,8%	0,85
Axis 3 - 0,47 m	467,0	474,0	9,2	8,9	339	343	21,5	23,0	95,6%	0,18
Axis 3 - 0,78 m	492,0	472,0	8,6	8,8	364	342	31,2	21,0	143,2%	0,29
Axis 3 - 1,09 m	496,0	474,0	8,7	8,9	361	342	29,7	21,2	136,6%	0,23
Axis 4 - 0,16 m	460,0	467,0	9,4	8,9	333	341	7,1	21,7	34,4%	0,79
Axis 4 - 0,47 m	445,0	447,0	9,1	8,8	335	341	20,0	21,0	98,9%	0,15
Axis 4 - 0,78 m	466,0	455,0	9,0	8,8	347	341	28,3	20,6	140,6%	0,27
Axis 4 - 1,09 m	447,0	445,0	9,0	8,8	341	341	27,2	20,8	133,5%	0,20
Min value										0,10
Mean value	486,0	476,8	8,7	8,8	354,9	343,4	24,4	20,8	114%	28%

Results of the best available measurement point (according to EN 15259, chapter 8.4)

Results		
Best sampling point		Axis 1 - 1,09 m
F_{rep} at the best available sampling point		123,6%
Ratios of measured values at the best available sampling point to mean value of all grid measurements for:		
NO_x	$c_{grid} / c_{grid\text{-}mean}$	114,0%
Oxygen content	$o_{grid} / o_{grid\ mean}$	90,7%
Temperature	$T_{grid} / T_{grid\ mean}$	106,0%
Velocity	$v_{grid} / v_{grid\ mean}$	124,4%

If the sampling at the best available measurement point fulfil the requirements of EN 14181 is shown by successful QAL2 .

Preliminary checks of the CEMS (function test) (1)

- State of analyser, Sampling system
  by visual test, condition of the installation site,
  properly protection from weather conditions
- Leak test
  by injection of test gases in the sampling probe
  (maximum deviation 1%)
- Linearity
  by injection of test gases in the sampling system
  at 20%, 40 %, 60%, 80 % of the measuring range
  (maximum deviation 5%)
- Zero and reference point drift between maintenance
  (maximum deviation at zero 2%;
  at reference point 4%)

Preliminary checks of the CEMS (function test) (2)

- Function check with example
  - Response time
    by injection of test gases in the sampling probe
    (maximum 200s)
  - Cross Interferences
    check the QAL1-Report for the components with maximum cross interference
    (maximum deviation 4%)
  - QAL3 requirements fulfilled?
- Certificate of proper installation (VDI 3950)

QAL 2

QAL2 - Calibration

- The AMS must prove
  - that it can be calibrated at a certain plant
    - If necessary different calibrations for different modes of operation
  - the uncertainty of the calibration fulfils the legal requirements

- The QAL2 must be conducted by an independent and skilled test lab with an accreditation (ISO 17025) or a designation (5.4 EN 14181)

QAL2 Basic idea

AMS

- Output is arbitrary measurement signal (e.g. mA)
- Measures under AMS conditions

QAL 2

SRM

- Measures mass concentration under standard conditions
- Gives **true** value by definition

Steps of QAL2

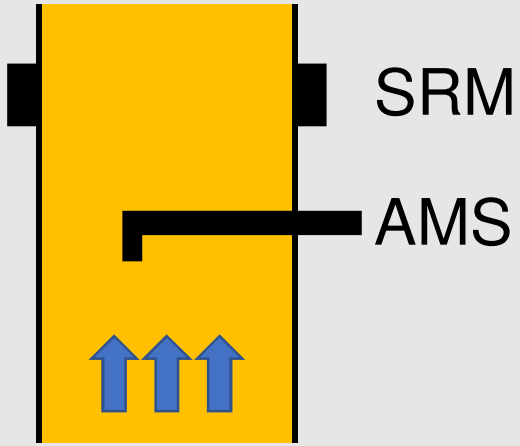
- Function check (see AST)
- SRM Measurements
- Data evaluation
- Calculation of the calibration function
- Variability check
- Report

SRM Measurements – the true value

- The AMS is calibrated against a "true" value. By definition the true value is determined by a **standard reference method** (SRM)
  - In the context of EN 14181 → SRM according CEN standards
- If only EPA measurements are available the equivalence to CEN standards should be ensured:
  - Basics: EPA 1 vs EN 15259
  - NO_x: EPA 7E vs EN 14792
  - CO: EPA 10A vs EN 15058
  - O2: EPA 3A vs EN 14789

Basics: Measurement strategy EPA1 vs EN 15259

- The measurements should lead to the same results no matter whether the traverse points are determined according EPA1 or EN 15259
- EN 15259 allows to conduct the SRM measurements at one point if homogeneity has been proven (8.3, EN 15259)
- The duration of the SRM-measurements is at minimum 4 times the response time of the AMS or 30 minutes (whatever is longer, 6.3 EN 14181)



Nitrogenoxides EPA 7E vs EN 14792

- Many similarities between both standards. To ensure comparability of the results the following alteration / additional requirements are necessary:
  - QAL1-approved analyzers based on chemi-luminscence should be used for SRM measurements.
  - Analyzers based on a different technique may be used as SRM if the lab proves the equivalence according EN 14793
  - The NO2 → NO converter efficiency must be tested annually and should be >95%
  - The measurement uncertainty shall be calculated as described in EN 14792 (with examples) and should be <10% of ELV

Carbonmonoxide EPA 10 vs EN 15058
Oxygen EPA 3A vs EN 14789

- Many similarities between each pair of standards. To ensure comparability of the results the following alteration / additional requirements are necessary:
  - Oxygen: QAL1-approved analyzers based on a paramagnetic cell should be used for SRM measurements.
  - Carbonmonoxide: QAL1-approved NDIR analyzer should be used for SRM measurements.
  - Analyzers based on a different technique may be used as SRM if the lab proves the equivalence according EN 14793

SRM-Measurements - Requirements

- A valid calibration requires
  - At least 15 valid SRM/AMS data pairs
  - A spread of the SRM-measurements over 3 measurement days
  - The time interval between the start of each sample shall be longer than one hour
- During the measurements the operating conditions of the plant shall be varied in a way that a wide concentration spread is reached.

SRM-Measurements - Requirements

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  - A spread of the SRM-measurements over 3 measurement days

	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00
DAY 1	SRM	SRM	SRM	SRM	SRM														
DAY2	SRM	SRM	SRM	SRM	SRM														
DAY3	SRM	SRM	SRM	SRM	SRM														
DAY4																			
DAY5																			

  - Example invalid:
    - Only measurements in the morning
    - One measurements starts less than one hour after the beginning of the last on

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DAY 1	SRM		SRM		SRM		SRM		SRM										
DAY2	SRM		SRM		SRM		SRM		SRM										
DAY3	SRM		SRM		SRM		SRM		SRM										
DAY4																			
DAY5																			

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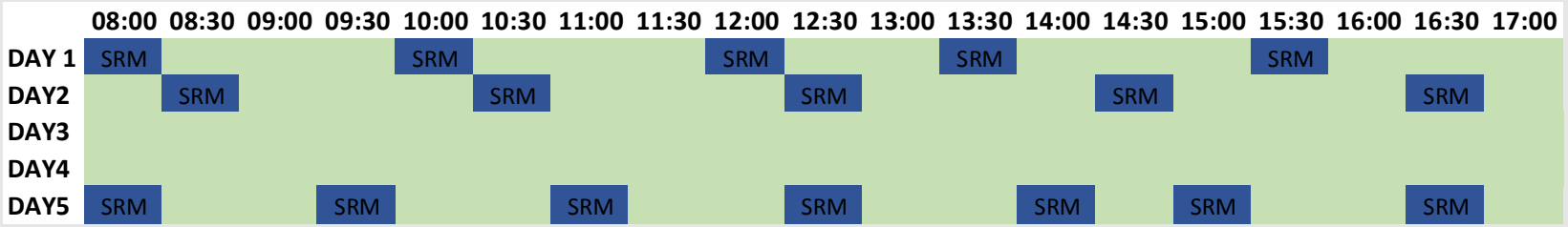
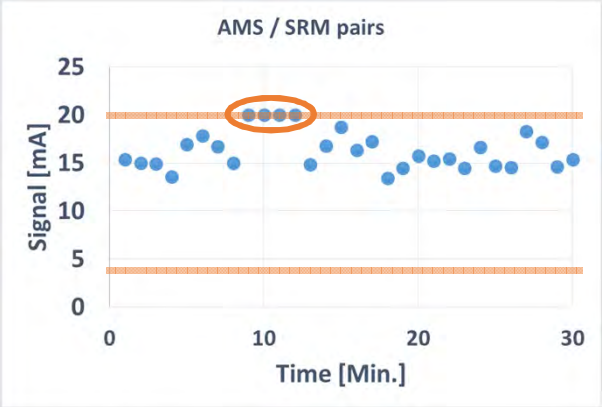


  - Example valid:
    - Sufficient Measurments (17)
    - Well-spread over the working days
    - Measurements completed within 4 weeks

Validity of data pairs

- The AMS signal is averaged over the SRM-sampling time
- The following values have to be excluded
  - Any signals outside the measurement range



  - Values recorded during internal checks, failure of the AMS, testgas applications
- The remaining AMS averaging time must be >90% of SRM measurement time.

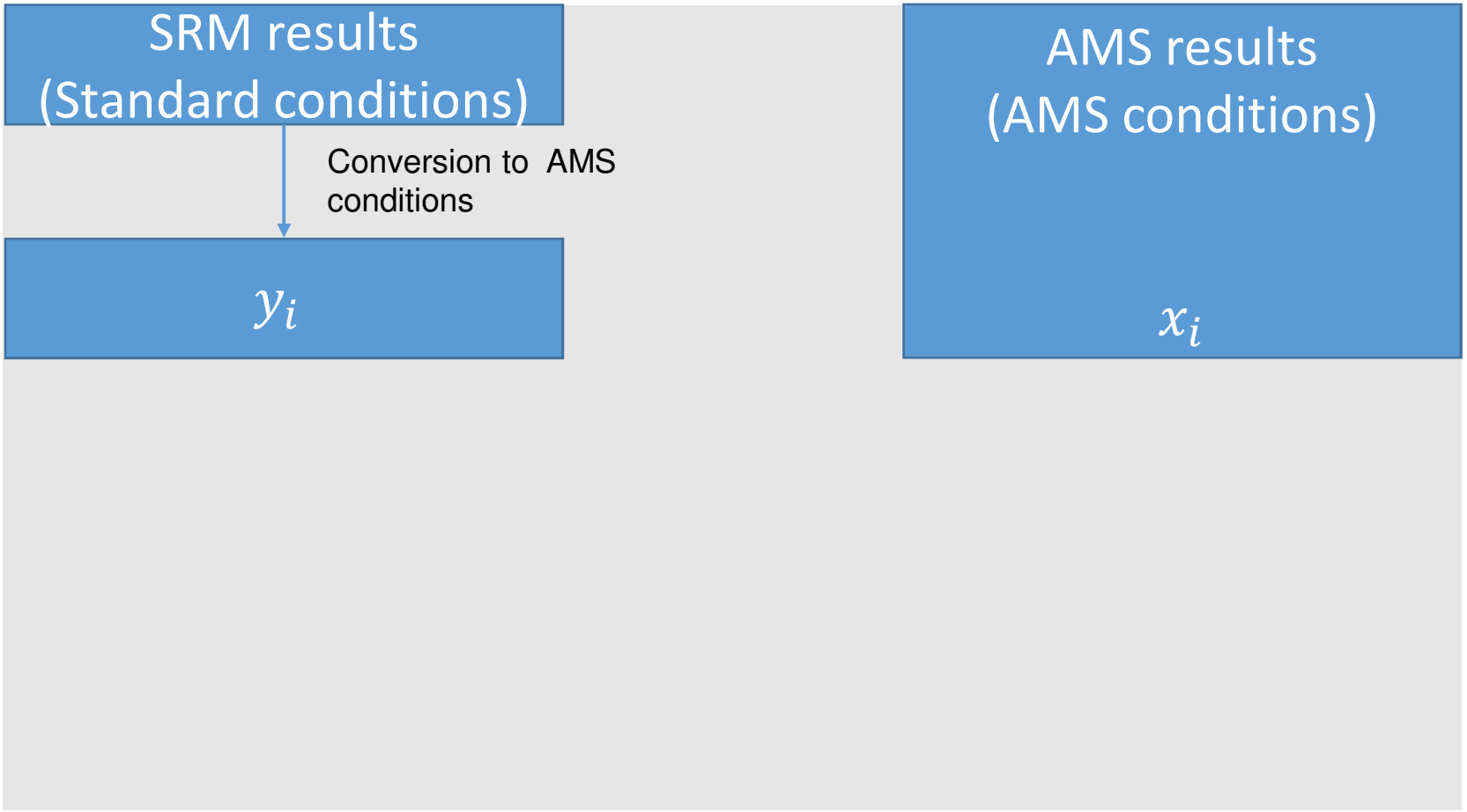
SRM-Measurements - Outliers

- The AMS/SRM data pairs shall be checked for outliers
- Outliers may only be removed if the deviation can be explained (e. g. failure of the flue gas dryer)
- Removed outliers do not count as valid measurements → It is strongly recommended to do more than 15 measurements.

SRM-Measurements

- In our case we have to measure NO_x, CO and O_2
- The measurements have to be conducted using SRM
- The test lab must prove that it meets the performance criteria of the corresponding SRM standard

Processing of AMS and SRM data pairs



Conversion to AMS conditions

Extractive AMS with flue gas drier

The stack conditions do not affect the measurement results → No conversion of the SRM results necessary

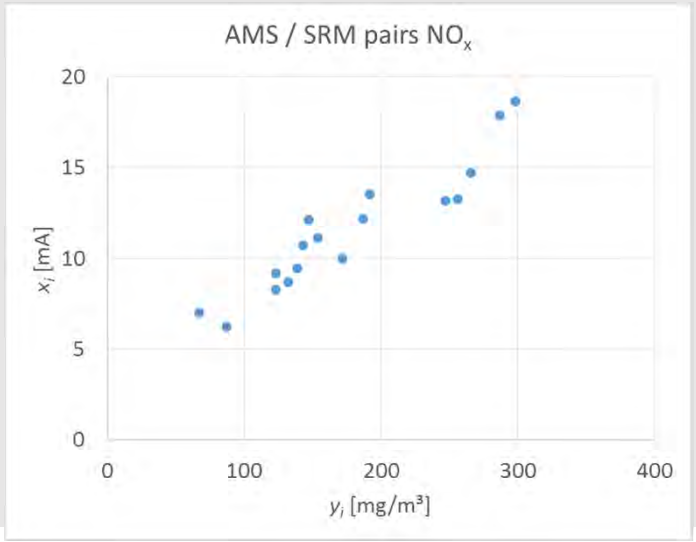
The flue gas parameters for SRM result conversion must be determined independently!

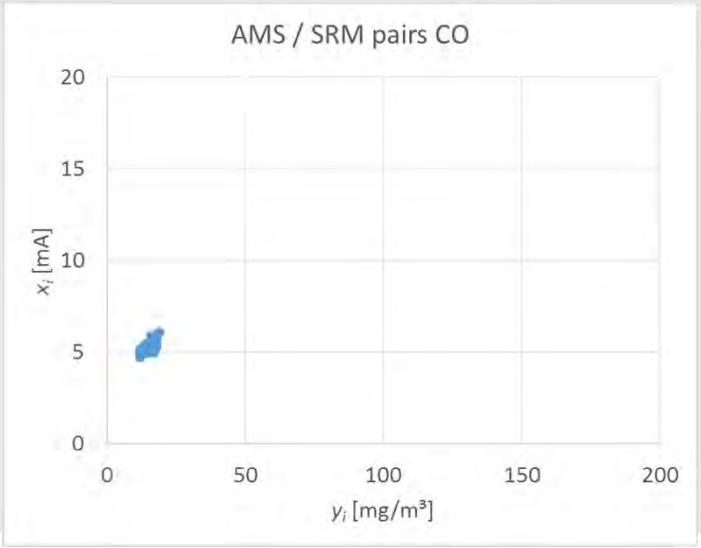
AMS data may only be used for conversion if the corresponding sensors were calibrated according EN 14181 before.

AMS' result and must be measured independently to convert the SRM results to AMS conditions.

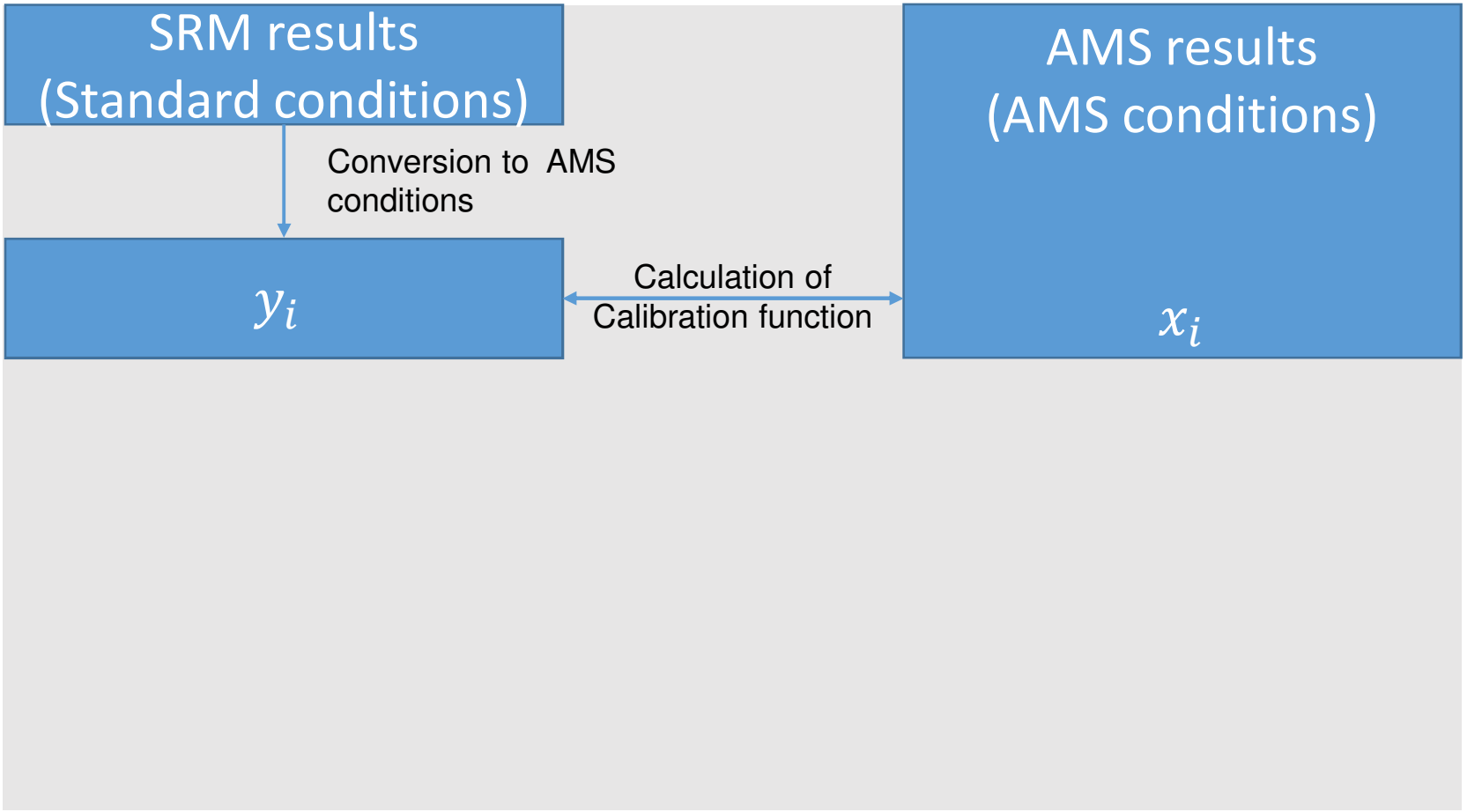
Conversion to AMS conditions – Our Example CO/NO_x

- The AMS measures extractively and features a gas drier
  - AMS condition can be considered as standard conditions (except oxygen reference) as the results are not (really) affected by changes of the stack conditions
  - SRM results are given at standard conditions (except oxygen reference)
  - No conversion necessary → direct calibration possible

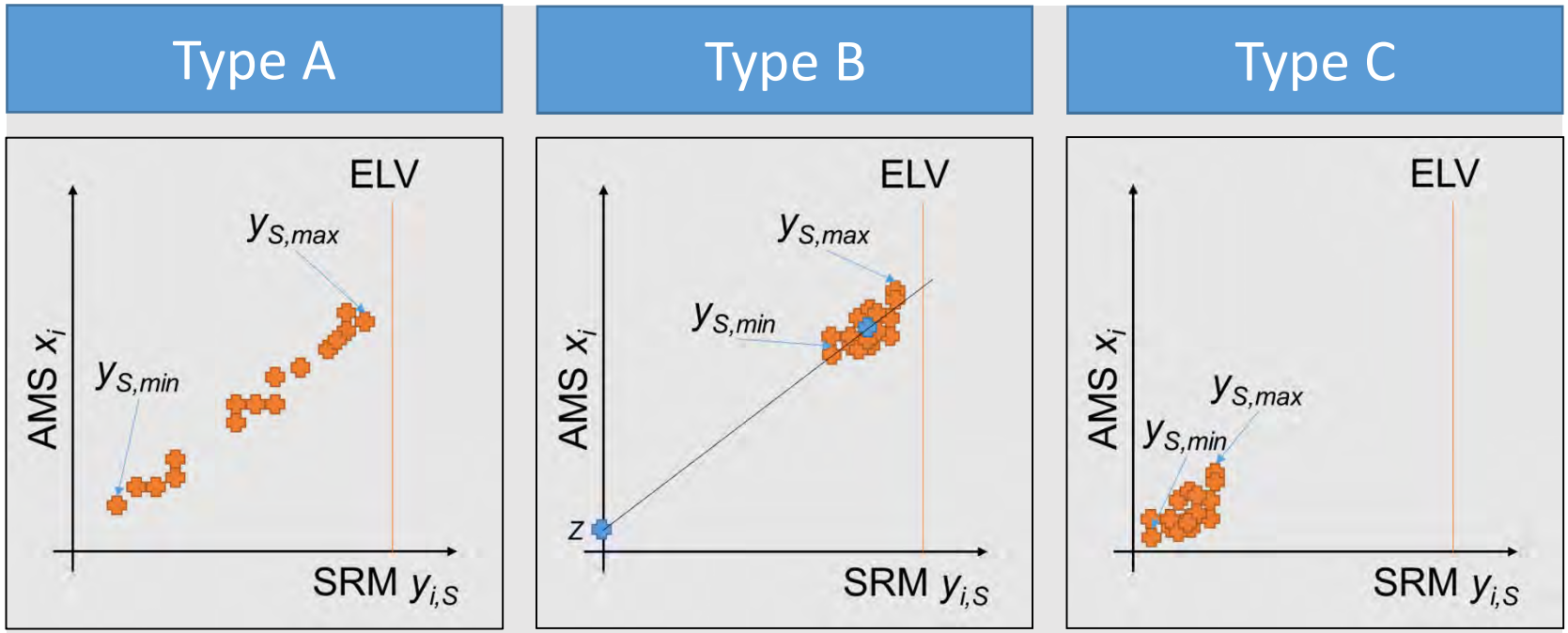




Processing of AMS and SRM data pairs



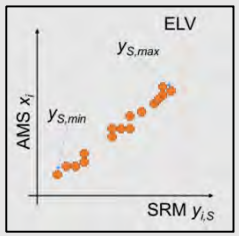
Methods for the Calculation of the calibration function



- For choosing the calibration strategy the spread of the SRM value as well as the distance from the ELV is relevant
- The reference oxygen (here 6 Vol.-%) of the ELV has to be taken into account $y_i \rightarrow y_{i,S}$. Independently derived SRM O_2 measurements must be used!

Methods for the Calculation of the calibration function

Type A

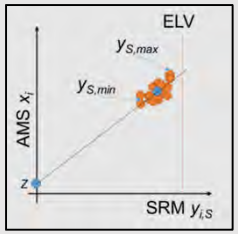


$y_{S,max} - y_{S,min} \geq \sigma_0 \cdot \text{ELV}$

with σ_0 being the maximum allowed relative uncertainty.

Calibration is derived via linear regression

Type B



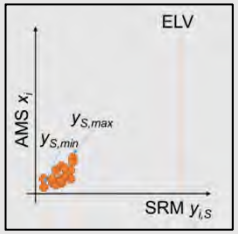
$y_{S,max} - y_{S,min} < \sigma_0 \cdot \text{ELV}$

and $y_{S,max} \geq 0{,}15 \cdot \text{ELV}$

Calibration is derived from two points

- Average of cloud $\bar{y}$
- Zero point measured with reference material

Type C



$y_{S,max} - y_{S,min} < \sigma \cdot \text{ELV}$

and $y_{S,max} < 0{,}15 \cdot \text{ELV}$

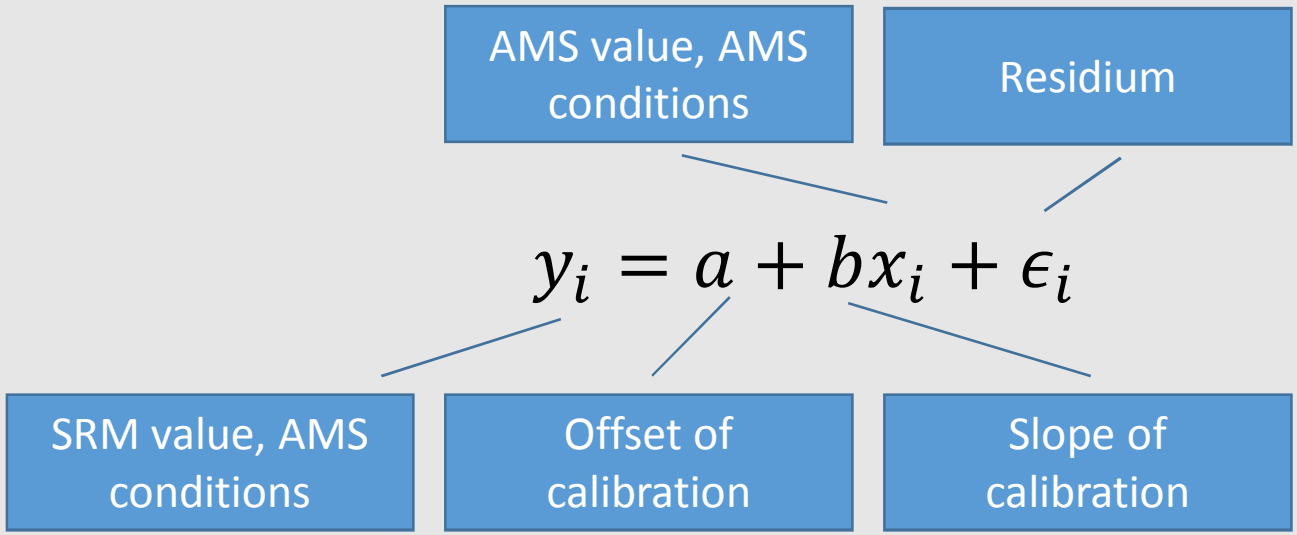
Calibration is performed with reference material close to zero and close to ELV

Our example

	CO	NO_x
σ_0 [%]	5,1	10,2
ELV [mg/m³]	150	300
$\sigma_0 \cdot$ELV [mg/m³]	7,7	30,6
$0{,}15 \cdot$ ELV [mg/m³]	22,5	45
$y_{S,max}$ [mg/m³]	21,76	338,64
$y_{S,max} - y_{S,min}$ [mg/m³]	6,98	261,92
$y_{S,max} - y_{S,min} \geq \sigma_0 \cdot \mathrm{ELV}$	✗	✓
$y_{S,max} \geq 0{,}15 \cdot \mathrm{ELV}$	✗	✓
	Type C calibration	Type A calibration

Type A calibration (No_x)

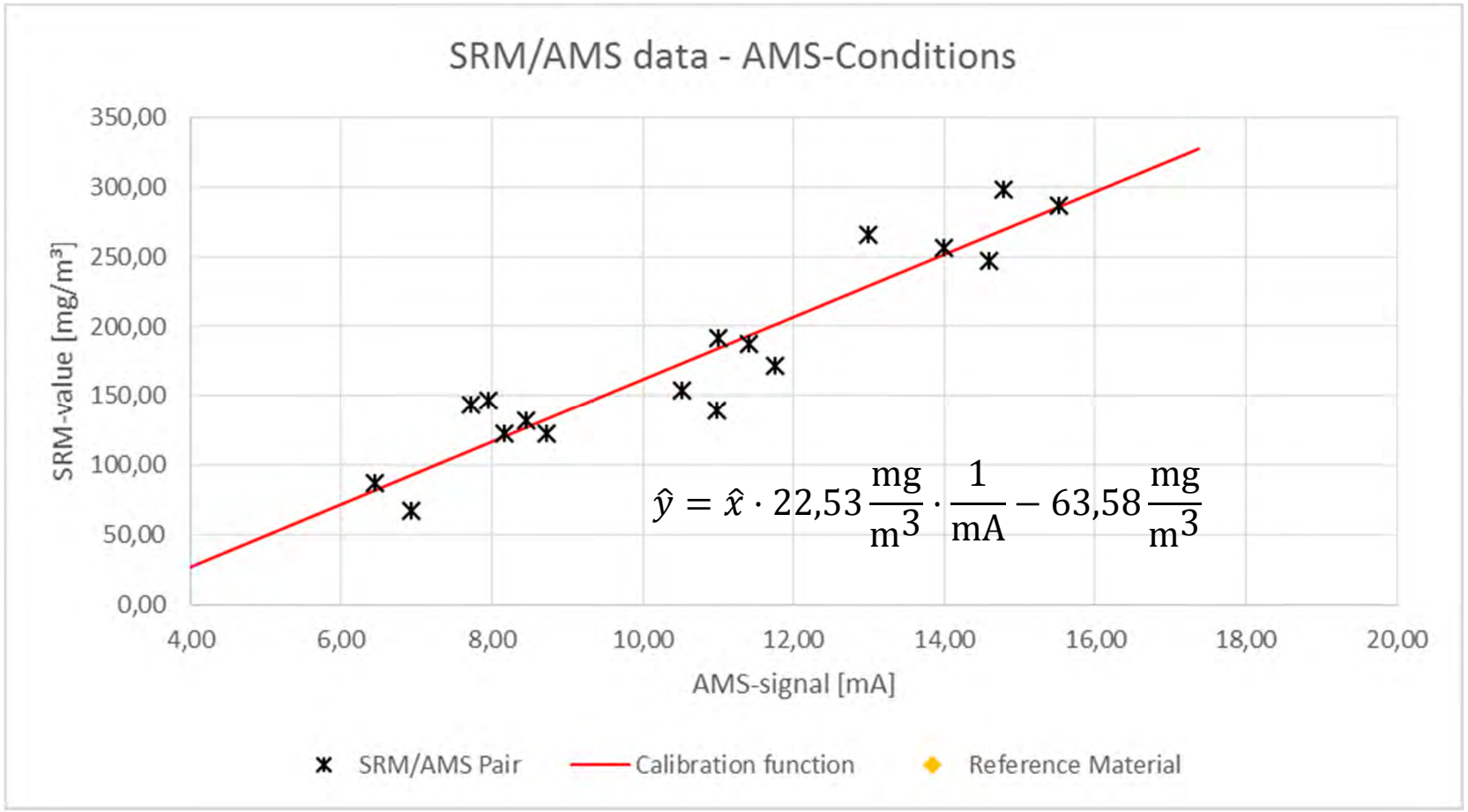
- A linear calibration function is used:



Linear Regression for the calibration function (Typ A)

- Auxiliary equations:
  - $\bar{x} = \frac{1}{N}\sum_i x_i$ — 177,6 mg/m³
  - $\bar{y} = \frac{1}{N}\sum_i y_i$ — 10,7 mA
- Linear Regression
  - $b = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sum_i (x_i - \bar{x})^2}$ — 22,5 mg/(m³mA)
  - $a = \bar{y} - b \cdot \bar{x}$ — -63,6 mg/m³

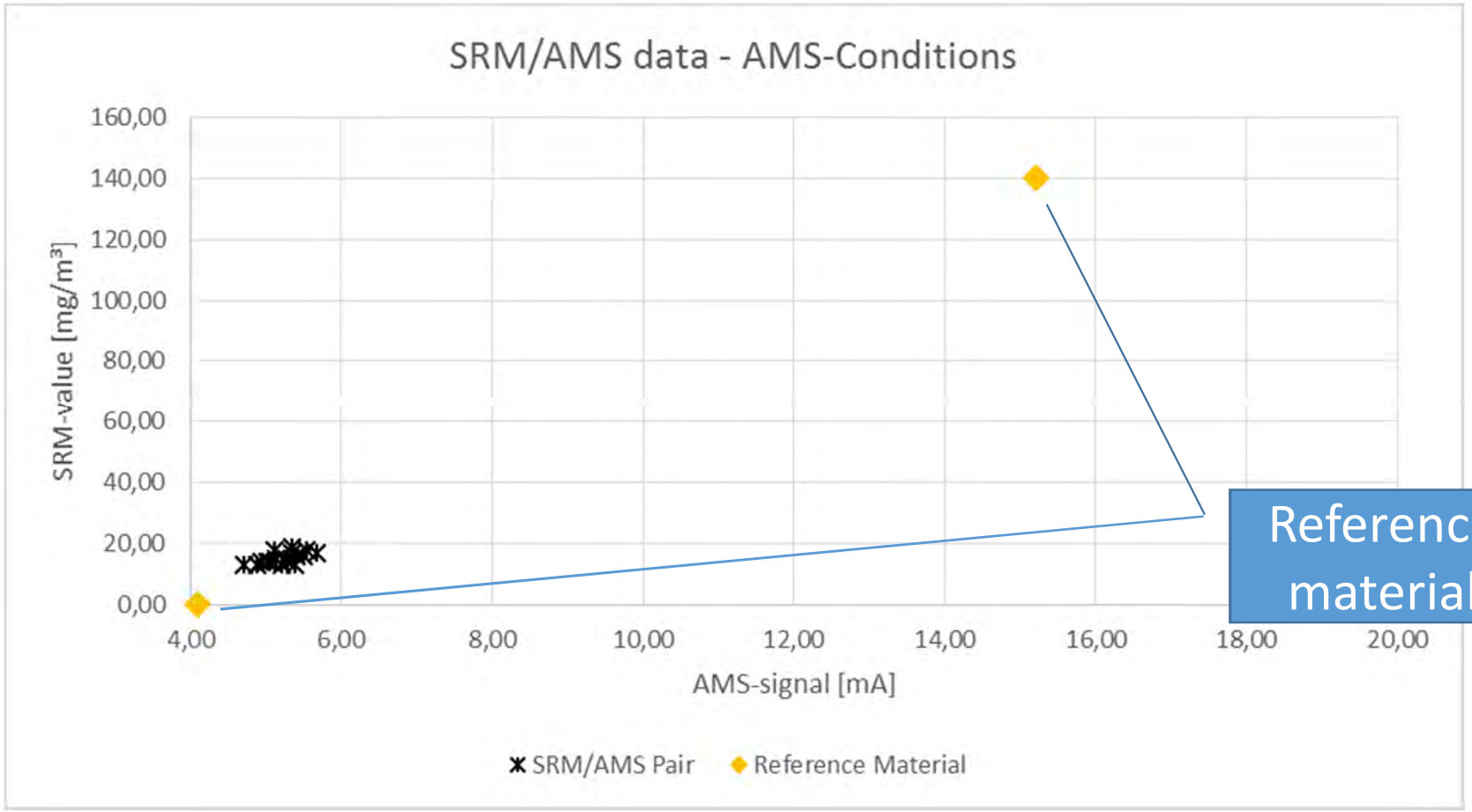
Calibration of NO_x - Diagramm



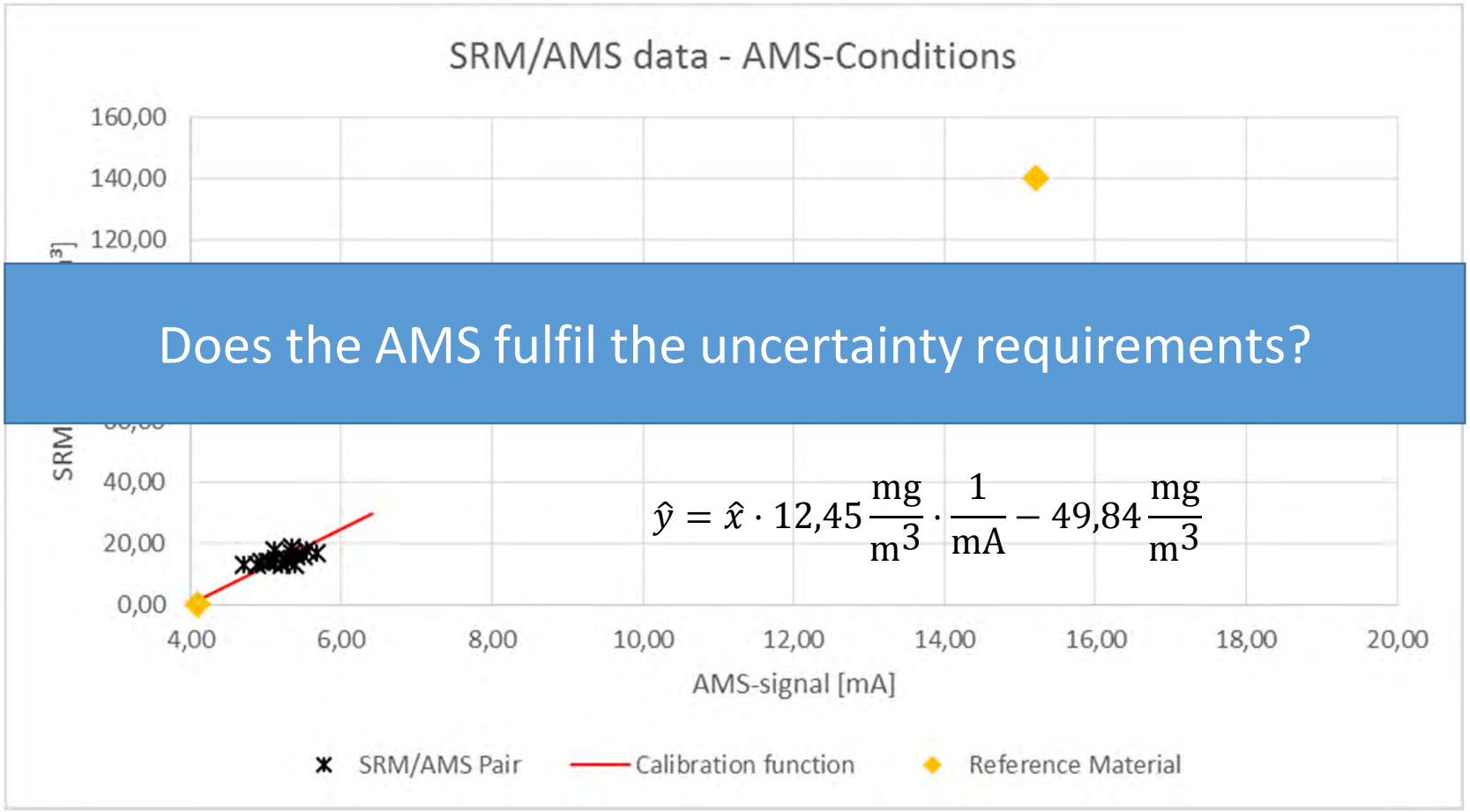
Type C calibration (CO)

- Two additional data pairs are generated by using reference material (e. g. test gas
  - e. g. test gas applied at the nozzle of the sampling line.
  - One data pair shall be close to „0“
  - One data pair shall be close to „ELV“
- The known concentration of the reference material is the SRM value and is to be converted in AMS conditions
- These data pairs are additional to the other data pairs.
- Afterwards the procedure is the same as with „A“

Calibration for CO - diagram

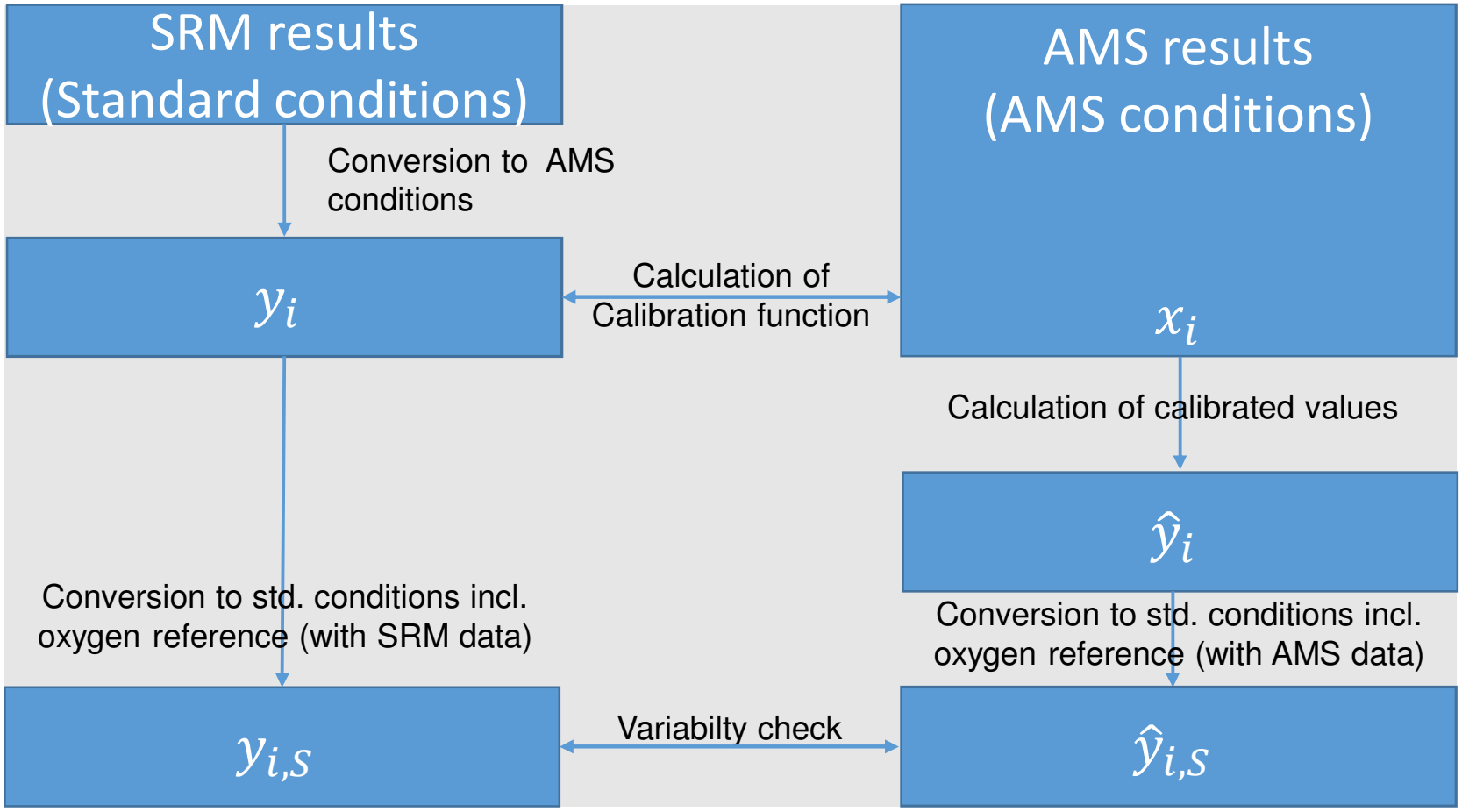


Calibration for CO - diagram



Does the AMS fulfil the uncertainty requirements?

Processing of AMS and SRM data pairs



Variability check

- Each AMS/SRM data pair $(y_i; x_i)$ is converted to standard conditions including oxygen reference $(y_{S,i}; \hat{y}_{S,i})$.
  - The conversion is performed by using only the data of the corresponding measurements (i. e. AMS data is used for the conversion of AMS data and independently measured SRM data for the conversion of the SRM data)
- Only data pairs from SRM measurements are considered in the variability check. Data pairs from reference materials are **not** included.

Variability Check

- The residuum of each AMS/SRM pair is calculated:

$$D_i = y_{S,i} - \hat{y}_{S,i}$$

- The average of the residua is calculated

$$\overline{D} = \frac{1}{N}\sum_i D_i$$

- The deviation of the calibration is calculated

$$s_D = \sqrt{\frac{1}{N-1}\sum_i (D_i - \overline{D})^2}$$

The variability check

$$s_D \leq \sigma_0 \cdot k_v$$

Correction for limited number of measurements

	CO	NO_x
σ_0 [%]	5,1	10,2
ELV [mg/m³]	150	300
σ_0 ·ELV [mg/m³]	7,7	30,6
s_D [mg/m³]	2,78	26,23
k_v	0,98	0,98
$s_D \leq \sigma_0 \cdot k_v$	✓	✓

If the variability check fails…

- AMS suitable
  - Cross-sensitivities?
- Check influence of sampling position
  - Homogeneity sufficient?
- Check influence of SRM uncertainty?
  - If uncertainty high, improve measurement technique
- Check uncertainty of state variables (p, T, O_2, …)

Calibration (Range of validity)

- The calibration range is the larger value of:
  - $1{,}1 \cdot \hat{y}_{S,max}$ (Reference material is **not** considered)
  - $0{,}2 \cdot \mathrm{ELV}$

	CO	NO_x
ELV [mg/m³]	150	300
0,2 ·ELV [mg/m³]	30	60
$\hat{y}_{S,max}$ [mg/m³]	24	330
$1{,}1 \cdot \hat{y}_{S,max}$ [mg/m³]	26	363
Calibration range [mg/m³]	0 - 30	0 – 363

Check of calibration range violations → Operator

- The operator has to check weekly for possible calibration range violations.
- A new QAL2 within 6 month is required if the weekly check of calibration range compliance fails. The check fails, if
  - For more than 5 weeks since the last AST more than 5% of the measurement values of a week exceeded the calibration range.
  - More than 40% of the measurement values of one week exceeded the calibration range.

Report of QAL2

- The Israeli government will release a template.
- The report must feature:
  - Information about the lab (Person in charge, …)
  - A detailed description of the industrial site and the sampling positions
  - A detailed description of the AMS and the SRM
  - A detailed description of the operating conditions of the plant during the measurements
  - Measurement data including graphical presentation
  - Description of outlier treatment
  - Statement whether the requirements are fulfilled
  - Documentation that the calibration function was stored in the data management system / the analyser

QAL 3

Ongoing quality assurance during operation (QAL3)

- Check of the zero point and span point, at least once in the maintenance interval of the AMS
- Documentation by use of control charts.
- Alternatively, the zero point and span point drifts can be determined and evaluated manually or continuously by functions implemented in the software.

Ongoing quality assurance during operation (QAL3)

- Documentation by use of control charts.
- Alternatively, the zero point and span point drifts can be determined and evaluated manually or continuously by functions implemented in the software.
- Replace of gas bottles:
  additional checks are recommend
  Compare average of five span readings with the “old” bottle with the average of five span readings with the “new” bottle

QAL3: Performance-data

- The **standard deviation s_{AMS}** needed for the control charts shall be determined from data obtained in the suitability test (see Clause 7.3 of DIN EN 14181).
  Consider the specific plant conditions and not the test conditions during the suitability test.
- A **minimum value of 3 % of the measuring range** shall be used for the standard deviation s_{AMS}. This avoids that the control charts wrongly indicate an out of range operation in case of very small standard deviations

QAL3: Performance-data

- Version B according to EN 14181 (7.4.3)
  The **standard deviation s_{AMS} = 25%** of the maximum allowed measurement uncertainty for this compound.
  E. g. for CO = 2,5 %
  for NO_x = 5 %

Note: the maximum allowed measurement uncertainty should be calculated to AMS conditions !

AFNOR recommendation for standard deviation s_{AMS}

Table 4 – AFNOR method for calculating S_{AMS} for incineration installations

Determinand	Uncertainty allowance	DA ELV in $mg.m^{-3}$	S_{AMS} in %	S_{AMS} in $mg.m^{-3}$
CO	10	50	2	1
NOx	20	200	2	4
SO_2	20	50	2	1
TOC	30	10	3	0.3
HCl	40	10	10	1
HF	40	1	20	0.2
Particulate	30	10	10	1

QAL3: Performance-data

- Recommendation:
  The **standard deviation s_{AMS}** should not below **3 % of the measuring range**
  This avoids that the control charts wrongly indicate an out of range operation in case of very small standard deviations.

QAL3: thresholds

Alarm threshold = 5 % upper range value

Warning threshold = 2,5% upper range value

- If drift is above warning threshold then perform drift correction
- If drift is above alarm threshold then perform service/repair

Example

upper range value = 200 mg/m³

- Then Alarm threshold = 10 mg/m³
- Then Warning threshold = 5 mg/m³

zero point and span point deviation max. 10 mg/m³

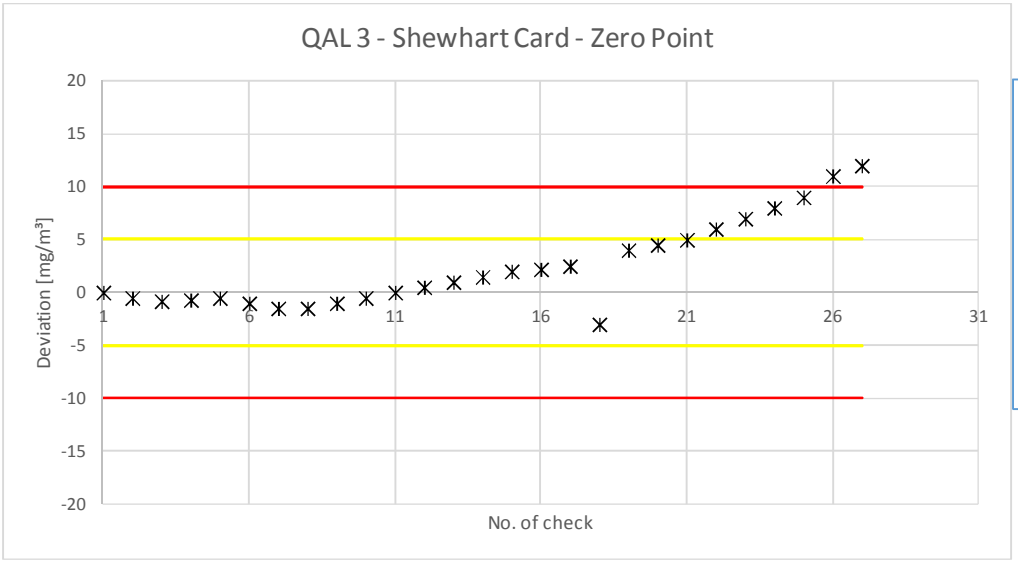
For spangas-concentration of 200 mg/m³
a measurement value
between 190 and 210 mg/m³ is acceptable

QAL3: Threshold for zero and span point

Warning Threshold @ Zero Point	5	mg/m³
Warning Threshold @ Zero Point	2,5	%
Alarm Threshold @ Zero Point	10	mg/m³
Alarm Threshold @ Zero Point	5,0	%
Warning Threshold @ Span Point	5	mg/m³
Warning Threshold @ Span Point	2,5	%
Alarm Threshold @ Span Point	10	mg/m³
Alarm Threshold @ Span Point	5,0	%

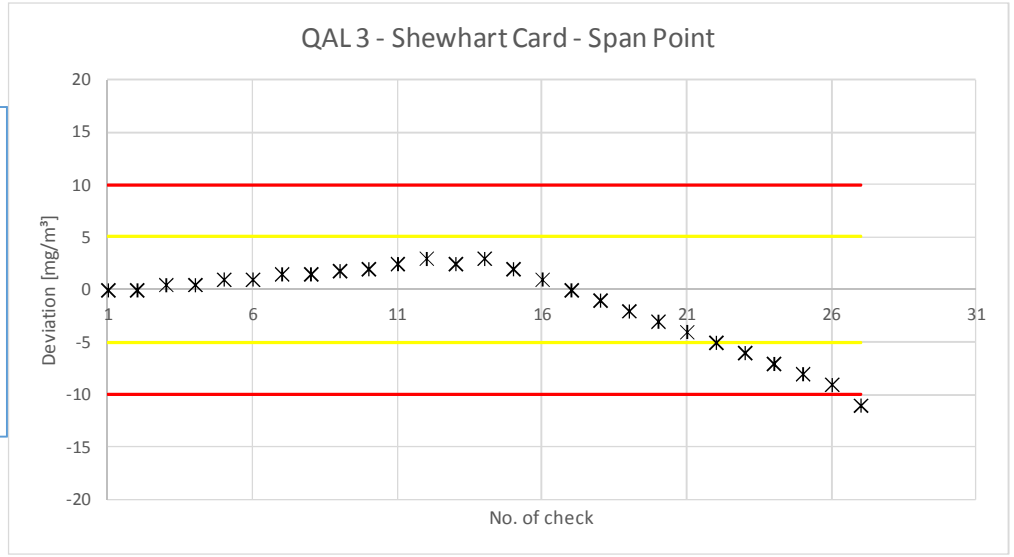
QAL3; Shewhart-controll chart; Example spreadsheet

		Zero Point		Span Point	
		x	Δ	*x*	Δ
No.	Date	[mg/m³]	[mg/m³]	[mg/m³]	[mg/m³]
1		0	0	200	0
2		-0,5	-0,5	200	0
3		-0,8	-0,8	200,5	0,5
4		-0,7	-0,7	200,5	0,5
5		-0,5	-0,5	201	1
6		-1	-1	201	1
7		-1,5	-1,5	201,5	1,5
8		-1,5	-1,5	201,5	1,5
9		-1	-1	201,8	1,8
10		-0,5	-0,5	202	2
11		0	0	202,5	2,5
12		0,5	0,5	203	3
13		1	1	202,5	2,5
14		1,5	1,5	203	3
15		2	2	202	2
16		2,2	2,2	201	1
17		2,5	2,5	200	0
18		-3	-3	199	-1
19		4	4	198	-2
20		4,5	4,5	197	-3
21		5	5	196	-4
22		6	6	195	-5
23		7	7	194	-6
24		8	8	193	-7
25		9	9	192	-8
26		11	11	191	-9
27		12	12	189	-11



QAL3: Plot for zero drift

QAL3: Plot for span drift



QAL3 Reporting

Records should include

- Details of the CEM with changes
- Manufacturer's service visit / routine maintenance
- Manufacturer's corrective actions / repair
- Operators routine maintenance and corrective actions
- Summary of the QAL3 baseline resets
- Tabulation and Plot of the zero and span drift

AST

AST (Annual Surveillance Test) (Mini QAL2)

- Functional check
  - Alignment / Cleanliness (visual inspection)
  - Sampling system leak tested
  - Zero / span checks
  - Response time
  - Linearity check
  - Check of the cross sensitivity
- Verification of calibration function
  - Requirements:
    minimum 5 parallel measurements with a SRM
  - evaluation

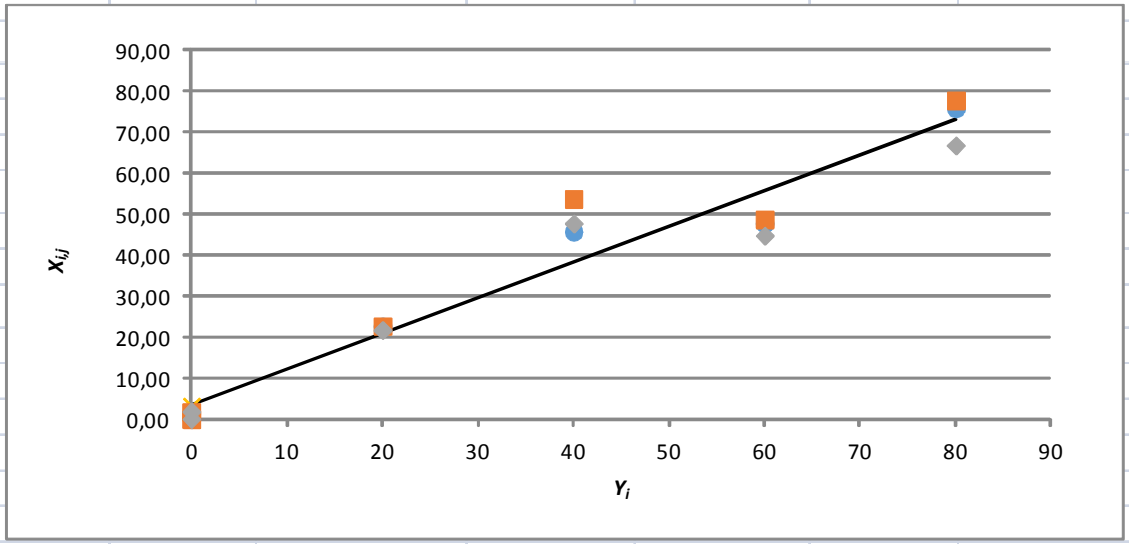
Linearity-Check (1)

Automated Measurement System (AMS)	
Type of analyzer	PG-350E (Horiba 2)
Serial number	G8UX9Y4U
Place of installation	Raum 259
Date of test	10.03.2016
Start and end time of test	09:56 - 11:18
Person in charge	Fr
Measurement unit	mg/m³
Upper measurement range limit [mg/m³]	300

ID Konzentration i	Reference Material Concentration y_i [mg/m³]	AMS Reading $x_{i,1}$ [mg/m³]	Reading $x_{i,2}$ [mg/m³]	Reading $x_{i,3}$ [mg/m³]	Average Readings $\dot{x}_c$ [mg/m³]	Auxilliary $S[Y_{i,j}*(X_i-X_z)]$	Auxilliary $(X_i-X_z)^2$	Residuum d_c [mg/m³]	rel. Residuum $d_{c,rel}$ [%]	Okay? $d_{c,rel} < 5\%$
1	0	0,3	0,3	0,4	0,333333	-33,33	1111,11	-3,17	**-1,06**	
2	80	76,0	78,0	67,0	73,666667	10313,33	2177,78	0,43	**0,14**	
3	20	23,0	23,0	22,0	22,666667	-906,67	177,78	1,73	**0,58**	
4	40	46,0	54,0	48,0	49,333333	986,67	44,44	10,97	**3,66**	
5	60	48,0	49,0	45,0	47,333333	3786,67	711,11	-8,47	**-2,82**	
6	0	1,7	2,1	2,2	2,000000	-200,00	1111,11	-1,50	**-0,50**	
7					--	0,00	--	--	--	

Linearity-Check (2)

Average y_z	[mg/m³]	33,33
Linear Regressions		
Equation		$x_i = A' + B(y_i - y_z)$
Offset A'	[mg/m³]	32,56
Slope B		0,87
Equation		$x_i = A + B \cdot y_i$
Offset A	[mg/m³]	3,50
Slope B		0,87
Result		
Linearity check passed		**Yes**



AST (Annual Surveillance Test)

- Report
  1. Summary
  2. Information about the plant and the CEMS
  3. Information about the test lab and the used SRM
  4. Data and calculations (QAL2 or AST) including the results of the check (validity and variability) of the calibration curve with minimum 5 SRM-measurements
  5. Results of the functional test
  - Annexes: supporting data / information of the test lab

1. Summary

- Information about the test lab (name, accreditation)
- Title of the report (QAL2 or AST)
- Information about the plant / stack (name, address, contact person)
- Monitored parameters
- Date of the parallel measurements
- Date and version number of the report

2. Information about the plant and the CEMS

- Information about the plant / stack (name, address, contact person)
  - Monitored pollutants and ELVs
  - Description of the plant-process
  - Type of the Fuel
- Monitoring conditions (e.g. stack, sampling ports, homogeneity check done?)
- CEMS at the plant
  description for each pollutant and exhaust boundary conditions (O_2, moisture, flow)

3. Information about the test lab and the used SRM

- Test lab
  - Name and accreditation cert. Number
- Used SRM
  - SRM standard applied
  - Accreditation of the method
  - Equipment (e. g. Analyzer)
  - Uncertainty of method

4. Data and calculations (1)

- Raw monitoring data for the parallel measurements
  - Start and end times
  - Raw SRM and AMS results including results for temperature, oxygen and moisture
- Standardised monitoring data for SRM and AMS
- Plot time series of standardised AMS versus standardised SRM data
- Calculation and procedure (outlier check)
- Table: AMS data used to calculate calibrated values

4. Data and calculations (2)

- X-y Plot of AMS versus SRM data (at AMS-conditions)
- Table with data used for variability test
- Calculation of the variability / acceptance test
- X-y Plot of calibrated AMS versus SRM data (at standard-conditions)

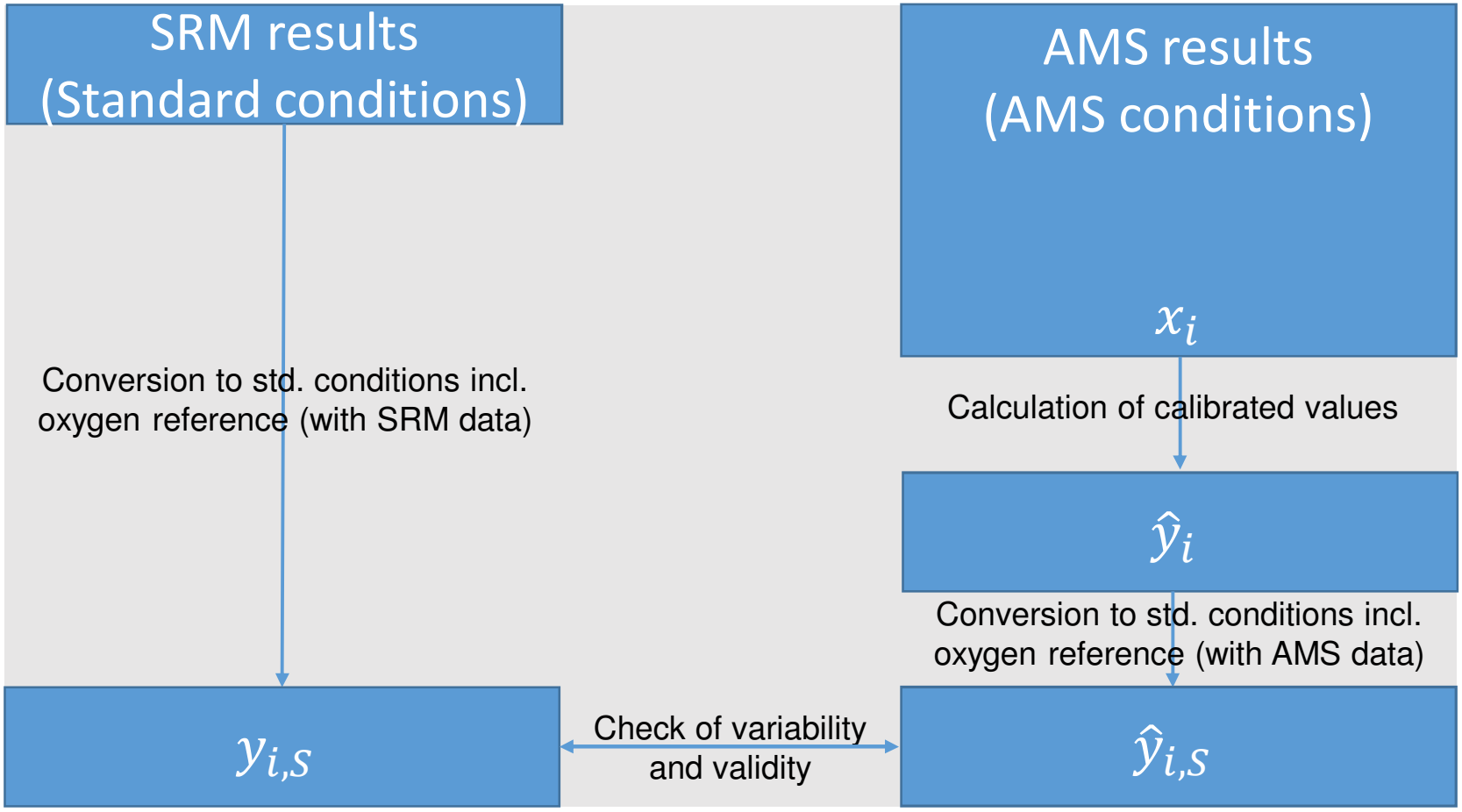
4. Results of the functional tests

- Alingment and cleanliness (visual check)
- Sampling systems (visual check)
- Leak testing according to CEMs manual
- Zero / span check
- Linearity
- Interferences (cross sensitivity)
- Zero / span drift (check of QAL3)
- Response time

AST - Verification of the calibration function

- At least 5 valid measurements with a SRM
- The measurements shall be spread over one day
- The AMS/SRM data pairs shall be checked for outliers
  - If justified, they may be removed, but have to be documented in the report.

SRM Measurements

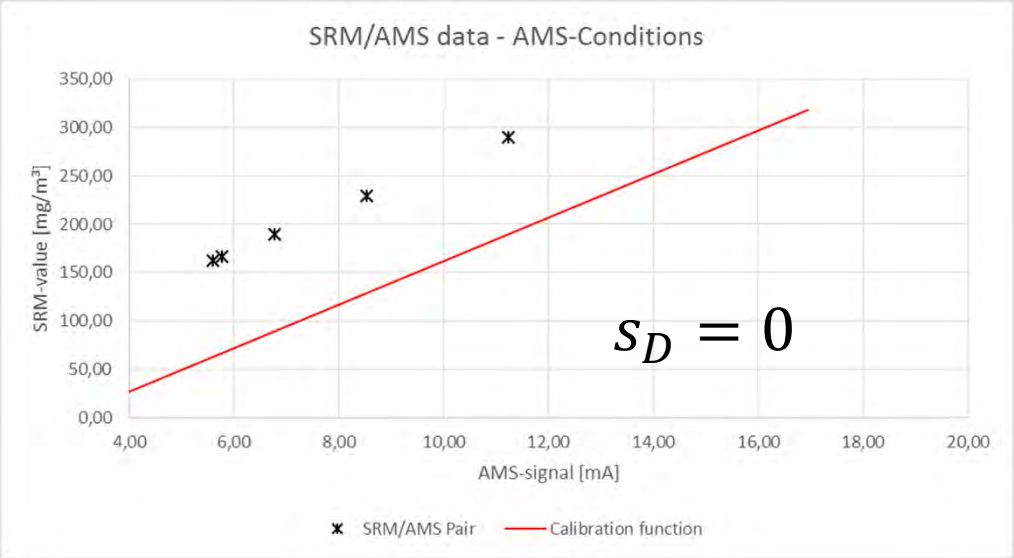


Check of the calibration function

- Criterion 1 – Variability check

$$s_D \leq 1.5 \cdot \sigma_0 \cdot k_\nu$$

  - Checks the uncertainty of the calibration function but does not see a constant offset:

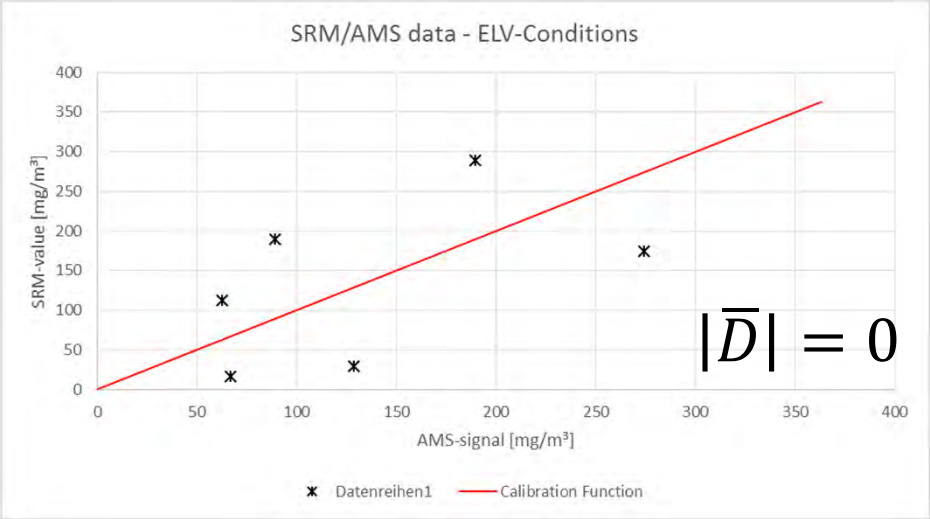


Check of the calibration function

- Criterion 2 – Validity check

$$|\bar{D}| \leq t_{0.95}(N-1) \cdot \frac{s_D}{\sqrt{N}} + \sigma_0$$

  - Checks for constant offsets, but does not check uncertainty:

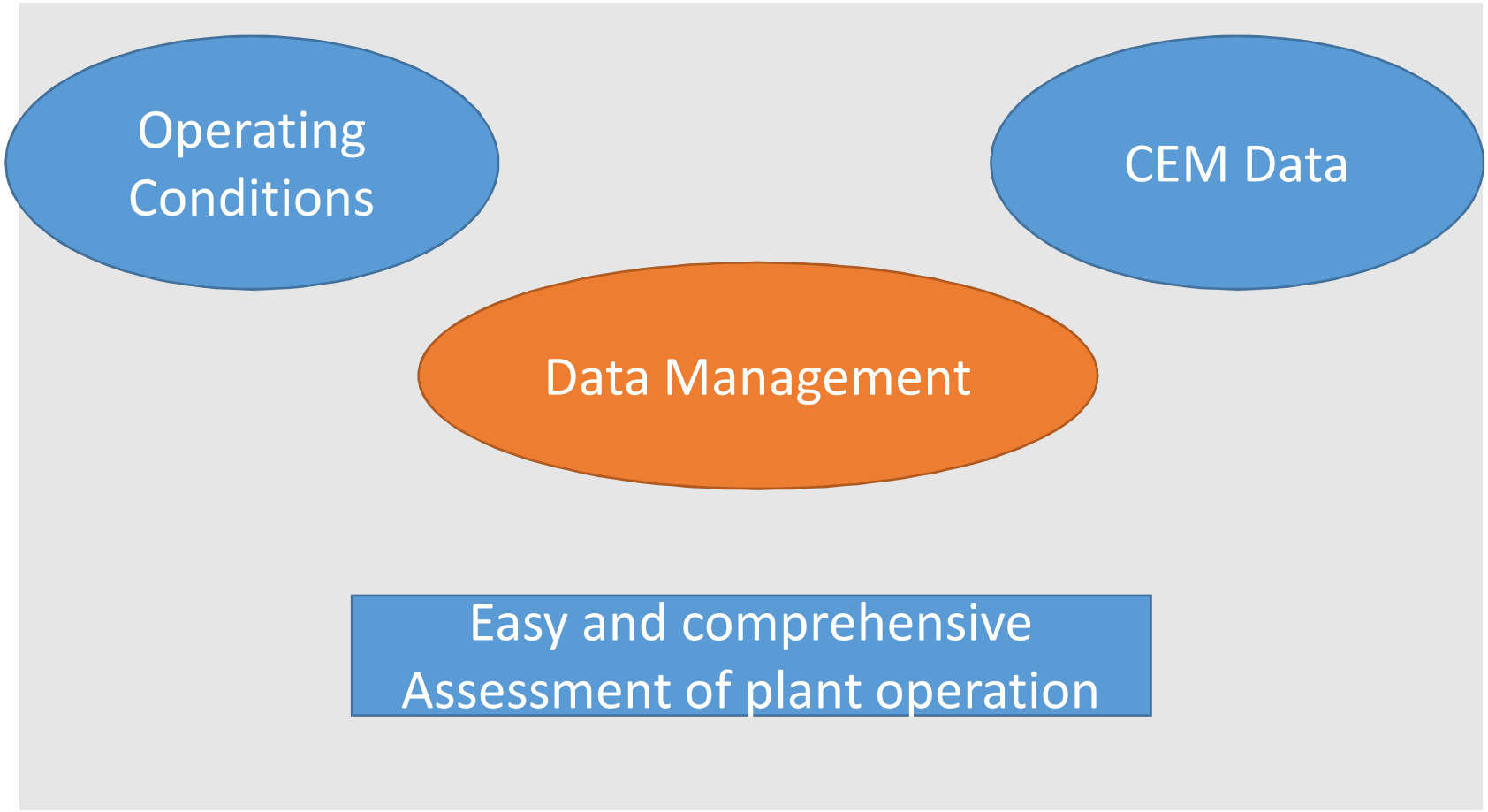


CEM Data Management in Germany

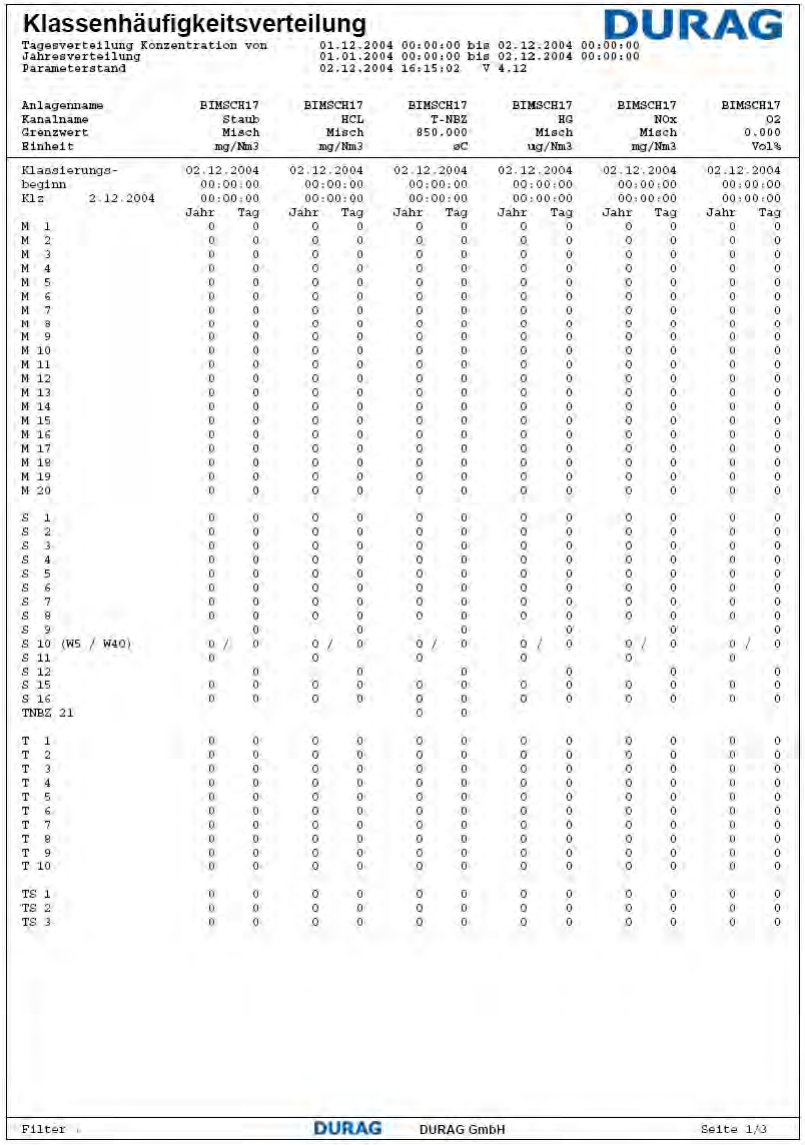
Legal Background in Germany

- To ease the evaluation of CEM data the data-management is standardized in Germnay
  - The procedures and requirements are described in „Bundeseinheitliche Praxis bei der Überwachung der Emissionen" (BEP)
  - There is no European standard for data management (yet)
- The data management is basically the creation of a histogram of all values

Data Management Scheme



Report Example



Klassenhäufigkeitsverteilung

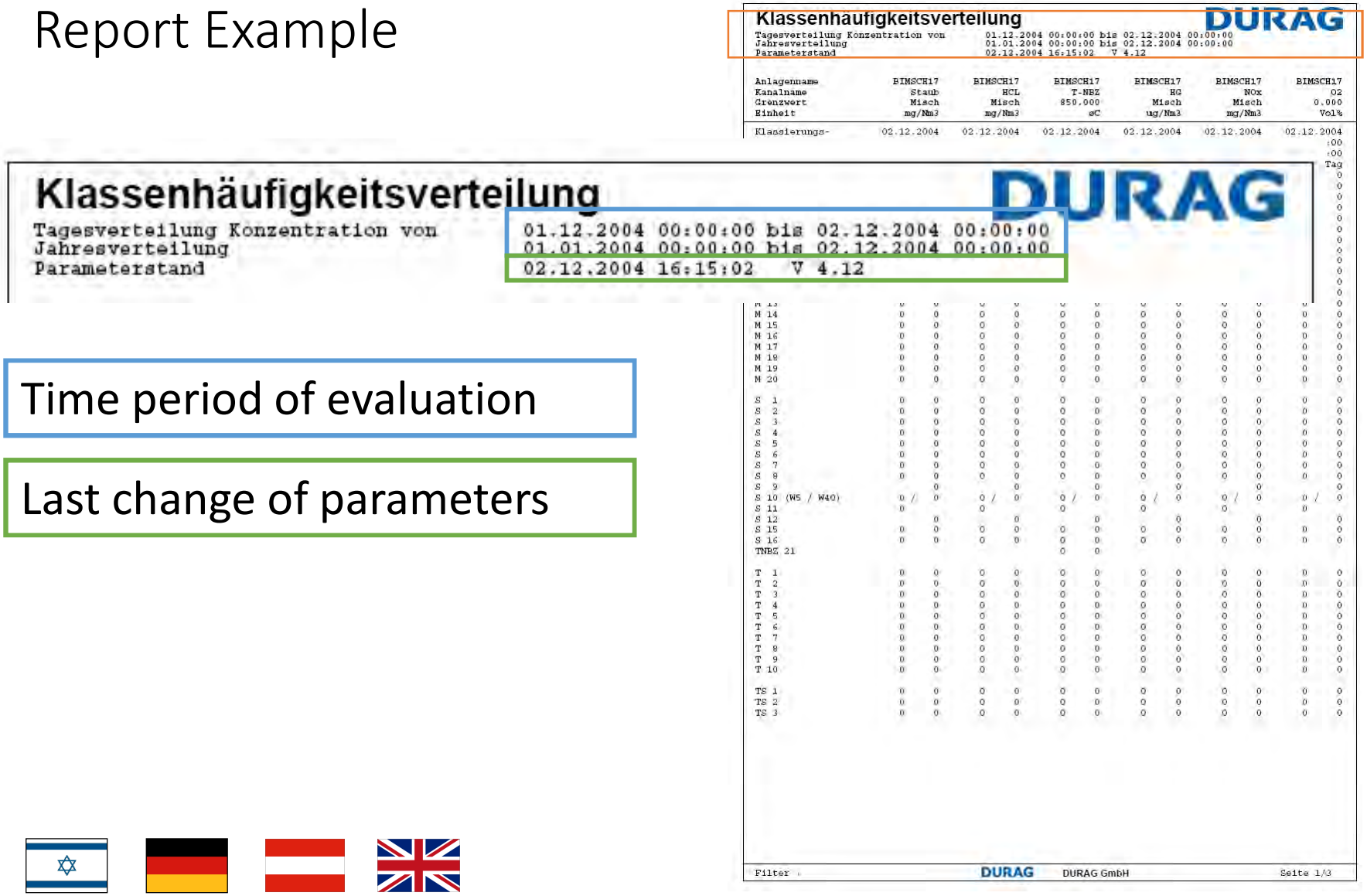
DURAG

Tagesverteilung Konzentration von 01.12.2004 00:00:00 bis 02.12.2004 00:00:00
Jahresverteilung 01.01.2004 00:00:00 bis 02.12.2004 00:00:00
Parameterstand 02.12.2004 16:15:02 V 4.12

Anlagenname	BIMSCH17		BIMSCH17		BIMSCH17		BIMSCH17		BIMSCH17		BIMSCH17	
Kanalname	Staub		HCL		T-NBZ		HG		NOx		O2	
Grenzwert	Misch		Misch		850.000		Misch		Misch		0.000	
Einheit	mg/Nm3		mg/Nm3		øC		ug/Nm3		mg/Nm3		Vol%	
Klassierungs-	02.12.2004		02.12.2004		02.12.2004		02.12.2004		02.12.2004		02.12.2004	
beginn	00:00:00		00:00:00		00:00:00		00:00:00		00:00:00		00:00:00	
Klz 2.12.2004	00:00:00		00:00:00		00:00:00		00:00:00		00:00:00		00:00:00	
	Jahr	Tag	Jahr	Tag	Jahr	Tag	Jahr	Tag	Jahr	Tag	Jahr	Tag
M 1	0	0	0	0	0	0	0	0	0	0	0	0
M 2	0	0	0	0	0	0	0	0	0	0	0	0
M 3	0	0	0	0	0	0	0	0	0	0	0	0
M 4	0	0	0	0	0	0	0	0	0	0	0	0
M 5	0	0	0	0	0	0	0	0	0	0	0	0
M 6	0	0	0	0	0	0	0	0	0	0	0	0
M 7	0	0	0	0	0	0	0	0	0	0	0	0
M 8	0	0	0	0	0	0	0	0	0	0	0	0
M 9	0	0	0	0	0	0	0	0	0	0	0	0
M 10	0	0	0	0	0	0	0	0	0	0	0	0
M 11	0	0	0	0	0	0	0	0	0	0	0	0
M 12	0	0	0	0	0	0	0	0	0	0	0	0
M 13	0	0	0	0	0	0	0	0	0	0	0	0
M 14	0	0	0	0	0	0	0	0	0	0	0	0
M 15	0	0	0	0	0	0	0	0	0	0	0	0
M 16	0	0	0	0	0	0	0	0	0	0	0	0
M 17	0	0	0	0	0	0	0	0	0	0	0	0
M 18	0	0	0	0	0	0	0	0	0	0	0	0
M 19	0	0	0	0	0	0	0	0	0	0	0	0
M 20	0	0	0	0	0	0	0	0	0	0	0	0
S 1	0	0	0	0	0	0	0	0	0	0	0	0
S 2	0	0	0	0	0	0	0	0	0	0	0	0
S 3	0	0	0	0	0	0	0	0	0	0	0	0
S 4	0	0	0	0	0	0	0	0	0	0	0	0
S 5	0	0	0	0	0	0	0	0	0	0	0	0
S 6	0	0	0	0	0	0	0	0	0	0	0	0
S 7	0	0	0	0	0	0	0	0	0	0	0	0
S 8	0	0	0	0	0	0	0	0	0	0	0	0
S 9		0		0		0		0		0		0
S 10 (W5 / W40)	0 /	0	0 /	0	0 /	0	0 /	0	0 /	0	0 /	0
S 11	0		0		0		0		0		0	
S 12		0		0		0		0		0		0
S 15	0	0	0	0	0	0	0	0	0	0	0	0
S 16	0	0	0	0	0	0	0	0	0	0	0	0
TNBZ 21					0	0						
T 1	0	0	0	0	0	0	0	0	0	0	0	0
T 2	0	0	0	0	0	0	0	0	0	0	0	0
T 3	0	0	0	0	0	0	0	0	0	0	0	0
T 4	0	0	0	0	0	0	0	0	0	0	0	0
T 5	0	0	0	0	0	0	0	0	0	0	0	0
T 6	0	0	0	0	0	0	0	0	0	0	0	0
T 7	0	0	0	0	0	0	0	0	0	0	0	0
T 8	0	0	0	0	0	0	0	0	0	0	0	0
T 9	0	0	0	0	0	0	0	0	0	0	0	0
T 10	0	0	0	0	0	0	0	0	0	0	0	0
TS 1	0	0	0	0	0	0	0	0	0	0	0	0
TS 2	0	0	0	0	0	0	0	0	0	0	0	0
TS 3	0	0	0	0	0	0	0	0	0	0	0	0

Filter : DURAG DURAG GmbH Seite 1/3

Report Example



Klassenhäufigkeitsverteilung

DURAG

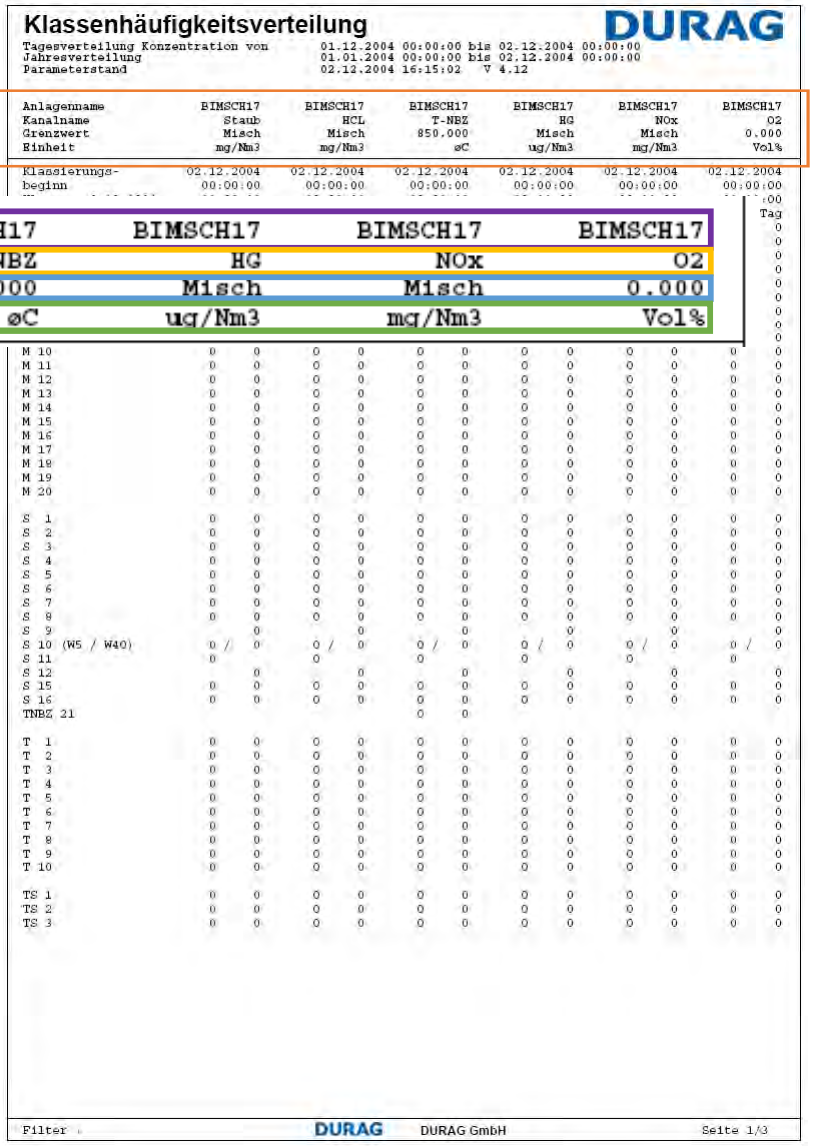
Tagesverteilung Konzentration von 01.12.2004 00:00:00 bis 02.12.2004 00:00:00
Jahresverteilung 01.01.2004 00:00:00 bis 02.12.2004 00:00:00
Parameterstand 02.12.2004 16:15:02 V 4.12

Anlagenname	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17
Kanalname	Staub	HCL	T-NBZ	HG	NOx	O2
Grenzwert	Misch	Misch	850.000	Misch	Misch	0.000
Einheit	mg/Nm3	mg/Nm3	øC	ug/Nm3	mg/Nm3	Vol%
Klassierungs-	02.12.2004	02.12.2004	02.12.2004	02.12.2004	02.12.2004	02.12.2004

Time period of evaluation

Last change of parameters

Report Example



Klassenhäufigkeitsverteilung

DURAG

Tagesverteilung Konzentration von 01.12.2004 00:00:00 bis 02.12.2004 00:00:00
Jahresverteilung 01.01.2004 00:00:00 bis 02.12.2004 00:00:00
Parameterstand 02.12.2004 16:15:02 V 4.12

Anlagenname	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17
Kanalname	Staub	HCL	T-NBZ	HG	NOx	O2
Grenzwert	Misch	Misch	850.000	Misch	Misch	0.000
Einheit	mg/Nm3	mg/Nm3	øC	ug/Nm3	mg/Nm3	Vol%
Klassierungs-beginn	02.12.2004 00:00:00	02.12.2004 00:00:00	02.12.2004 00:00:00	02.12.2004 00:00:00	02.12.2004 00:00:00	02.12.2004 00:00:00

Tag

M 10 0 0 0 0 0 0 0 0 0 0 0 0
M 11 0 0 0 0 0 0 0 0 0 0 0 0
M 12 0 0 0 0 0 0 0 0 0 0 0 0
M 13 0 0 0 0 0 0 0 0 0 0 0 0
M 14 0 0 0 0 0 0 0 0 0 0 0 0
M 15 0 0 0 0 0 0 0 0 0 0 0 0
M 16 0 0 0 0 0 0 0 0 0 0 0 0
M 17 0 0 0 0 0 0 0 0 0 0 0 0
M 18 0 0 0 0 0 0 0 0 0 0 0 0
M 19 0 0 0 0 0 0 0 0 0 0 0 0
M 20 0 0 0 0 0 0 0 0 0 0 0 0

S 1 0 0 0 0 0 0 0 0 0 0 0 0
S 2 0 0 0 0 0 0 0 0 0 0 0 0
S 3 0 0 0 0 0 0 0 0 0 0 0 0
S 4 0 0 0 0 0 0 0 0 0 0 0 0
S 5 0 0 0 0 0 0 0 0 0 0 0 0
S 6 0 0 0 0 0 0 0 0 0 0 0 0
S 7 0 0 0 0 0 0 0 0 0 0 0 0
S 8 0 0 0 0 0 0 0 0 0 0 0 0
S 9 0 0 0 0 0 0 0 0 0 0 0 0
S 10 (W5 / W40) 0 / 0 0 / 0 0 / 0 0 / 0 0 / 0 0 / 0 0
S 11 0 0 0 0 0 0 0 0 0 0 0 0
S 12 0 0 0 0 0 0 0 0 0 0 0 0
S 15 0 0 0 0 0 0 0 0 0 0 0 0
S 16 0 0 0 0 0 0 0 0 0 0 0 0
TNBZ 21 0 0 0 0 0 0

T 1 0 0 0 0 0 0 0 0 0 0 0 0
T 2 0 0 0 0 0 0 0 0 0 0 0 0
T 3 0 0 0 0 0 0 0 0 0 0 0 0
T 4 0 0 0 0 0 0 0 0 0 0 0 0
T 5 0 0 0 0 0 0 0 0 0 0 0 0
T 6 0 0 0 0 0 0 0 0 0 0 0 0
T 7 0 0 0 0 0 0 0 0 0 0 0 0
T 8 0 0 0 0 0 0 0 0 0 0 0 0
T 9 0 0 0 0 0 0 0 0 0 0 0 0
T 10 0 0 0 0 0 0 0 0 0 0 0 0

TS 1 0 0 0 0 0 0 0 0 0 0 0 0
TS 2 0 0 0 0 0 0 0 0 0 0 0 0
TS 3 0 0 0 0 0 0 0 0 0 0 0 0

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Anlagenname	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17
Kanalname	Staub	HCL	T-NBZ	HG	NOx	O2
Grenzwert	Misch	Misch	850.000	Misch	Misch	0.000
Einheit	mg/Nm3	mg/Nm3	øC	ug/Nm3	mg/Nm3	Vol%

Source

Component

ELV

Unit

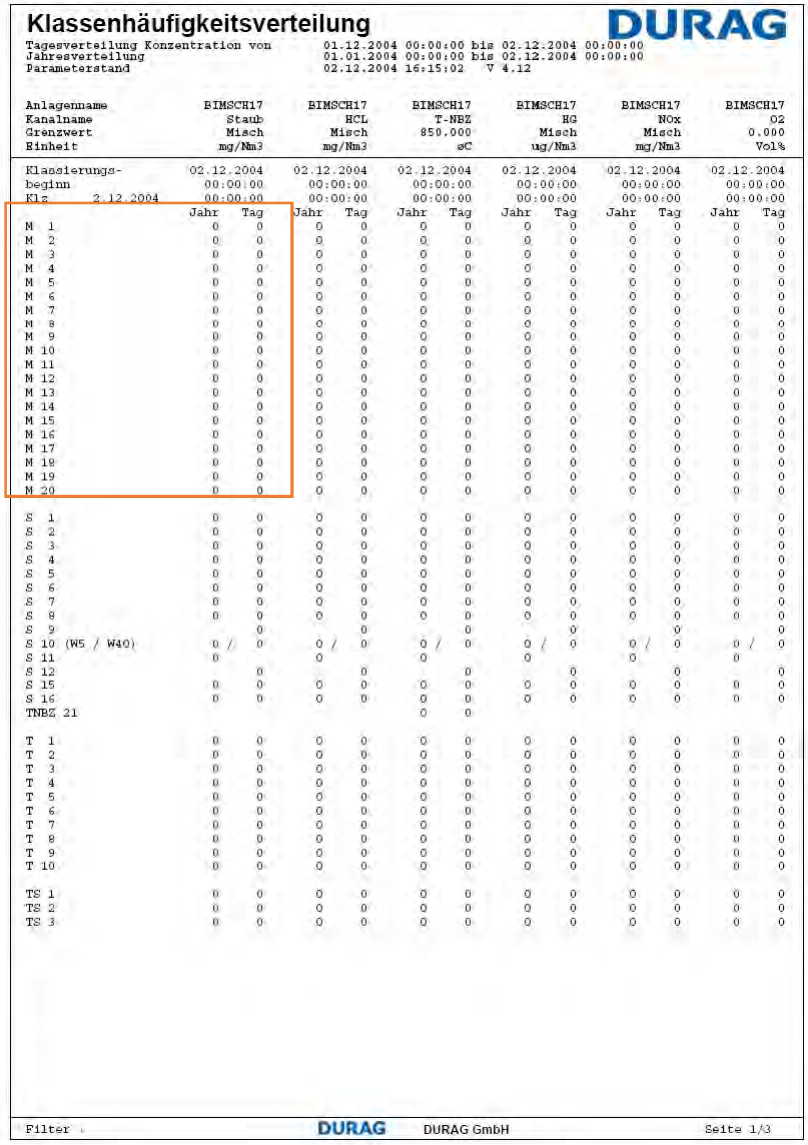
Report Example

	Jahr	Tag
M 1	0	0
M 2	0	0
M 3	0	0
M 4	0	0
M 5	0	0
M 6	0	0
M 7	0	0
M 8	0	0
M 9	0	0
M 10	0	0
M 11	0	0
M 12	0	0
M 13	0	0
M 14	0	0
M 15	0	0
M 16	0	0
M 17	0	0
M 18	0	0
M 19	0	0
M 20	0	0

Annualy

Daily

Twenty classes from 0 to 2x short term ELV



Klassenhäufigkeitsverteilung DURAG

Tagesverteilung Konzentration von 01.12.2004 00:00:00 bis 02.12.2004 00:00:00
Jahresverteilung 01.01.2004 00:00:00 bis 02.12.2004 00:00:00
Parameterstand 02.12.2004 16:15:02 V 4.12

Anlagenname	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17
Kanalname	Staub	HCL	T-NBZ	HG	NOx	O2
Grenzwert	Misch	Misch	850.000	Misch	Misch	0.000
Einheit	mg/Nm3	mg/Nm3	øC	ug/Nm3	mg/Nm3	Vol%
Klassierungs-	02.12.2004	02.12.2004	02.12.2004	02.12.2004	02.12.2004	02.12.2004
beginn	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00
Klz 2.12.2004	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00
	Jahr Tag	Jahr Tag	Jahr Tag	Jahr Tag	Jahr Tag	Jahr Tag
M 1	0 0	0 0	0 0	0 0	0 0	0 0
M 2	0 0	0 0	0 0	0 0	0 0	0 0
M 3	0 0	0 0	0 0	0 0	0 0	0 0
M 4	0 0	0 0	0 0	0 0	0 0	0 0
M 5	0 0	0 0	0 0	0 0	0 0	0 0
M 6	0 0	0 0	0 0	0 0	0 0	0 0
M 7	0 0	0 0	0 0	0 0	0 0	0 0
M 8	0 0	0 0	0 0	0 0	0 0	0 0
M 9	0 0	0 0	0 0	0 0	0 0	0 0
M 10	0 0	0 0	0 0	0 0	0 0	0 0
M 11	0 0	0 0	0 0	0 0	0 0	0 0
M 12	0 0	0 0	0 0	0 0	0 0	0 0
M 13	0 0	0 0	0 0	0 0	0 0	0 0
M 14	0 0	0 0	0 0	0 0	0 0	0 0
M 15	0 0	0 0	0 0	0 0	0 0	0 0
M 16	0 0	0 0	0 0	0 0	0 0	0 0
M 17	0 0	0 0	0 0	0 0	0 0	0 0
M 18	0 0	0 0	0 0	0 0	0 0	0 0
M 19	0 0	0 0	0 0	0 0	0 0	0 0
M 20	0 0	0 0	0 0	0 0	0 0	0 0
S 1	0 0	0 0	0 0	0 0	0 0	0 0
S 2	0 0	0 0	0 0	0 0	0 0	0 0
S 3	0 0	0 0	0 0	0 0	0 0	0 0
S 4	0 0	0 0	0 0	0 0	0 0	0 0
S 5	0 0	0 0	0 0	0 0	0 0	0 0
S 6	0 0	0 0	0 0	0 0	0 0	0 0
S 7	0 0	0 0	0 0	0 0	0 0	0 0
S 8	0 0	0 0	0 0	0 0	0 0	0 0
S 9	0	0	0	0	0	0
S 10 (W5 / W40)	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
S 11	0	0	0	0	0	0
S 12	0	0	0	0	0	0
S 15	0 0	0 0	0 0	0 0	0 0	0 0
S 16	0 0	0 0	0 0	0 0	0 0	0 0
TNBZ 21			0 0			
T 1	0 0	0 0	0 0	0 0	0 0	0 0
T 2	0 0	0 0	0 0	0 0	0 0	0 0
T 3	0 0	0 0	0 0	0 0	0 0	0 0
T 4	0 0	0 0	0 0	0 0	0 0	0 0
T 5	0 0	0 0	0 0	0 0	0 0	0 0
T 6	0 0	0 0	0 0	0 0	0 0	0 0
T 7	0 0	0 0	0 0	0 0	0 0	0 0
T 8	0 0	0 0	0 0	0 0	0 0	0 0
T 9	0 0	0 0	0 0	0 0	0 0	0 0
T 10	0 0	0 0	0 0	0 0	0 0	0 0
TS 1	0 0	0 0	0 0	0 0	0 0	0 0
TS 2	0 0	0 0	0 0	0 0	0 0	0 0
TS 3	0 0	0 0	0 0	0 0	0 0	0 0

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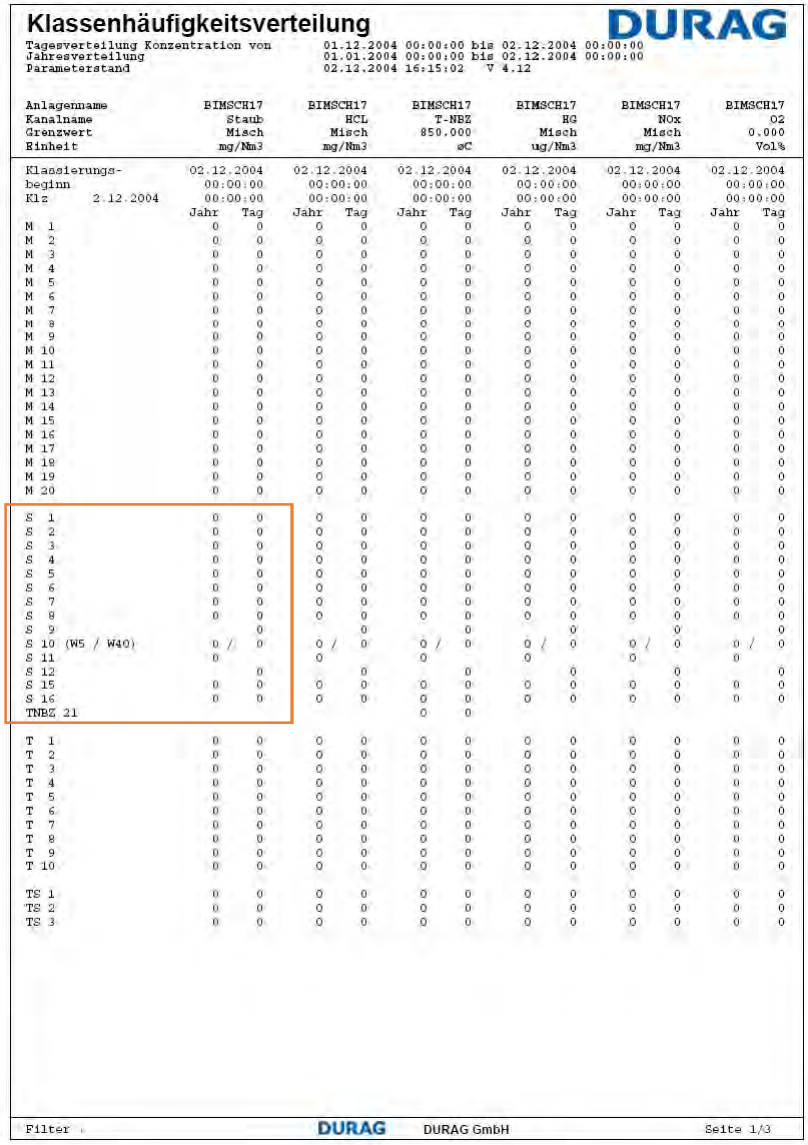
Report Example

S 1	ELV violation (>2xELV)	0	0
S 2	2/3 criterion not fulfilled	0	0
S 3	Substitute values used for standardization	0	0
S 4	Malfunction of AMS	0	0
S 5	Maintenance of AMS	0	0
S 6	Plant in Operation	0	0
S 7	2/3 criterion violated due to plant operation	0	0
S 8	Unplausible data	0	0
S 9	Value out of calibration range (weekly)	0	0
S 10	Value out of calibration range (long term)	0	0
S 11	Flue gas cleaning malfunction	0	
S 12			0
S 15		0	0
S 16		0	0
TNBZ 21			



Klassenhäufigkeitsverteilung DURAG

Tagesverteilung Konzentration von 01.12.2004 00:00:00 bis 02.12.2004 00:00:00
Jahresverteilung 01.01.2004 00:00:00 bis 02.12.2004 00:00:00
Parameterstand 02.12.2004 16:15:02 V 4.12

Anlagenname	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17	BIMSCH17
Kanalname	Staub	HCL	T-NBZ	HG	NOx	O2
Grenzwert	Misch	Misch	850.000	Misch	Misch	0.000
Einheit	mg/Nm3	mg/Nm3	øC	ug/Nm3	mg/Nm3	Vol%
Klassierungs-	02.12.2004	02.12.2004	02.12.2004	02.12.2004	02.12.2004	02.12.2004
beginn	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00
Klz 2.12.2004	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00
	Jahr Tag	Jahr Tag	Jahr Tag	Jahr Tag	Jahr Tag	Jahr Tag
M 1	0 0	0 0	0 0	0 0	0 0	0 0
M 2	0 0	0 0	0 0	0 0	0 0	0 0
M 3	0 0	0 0	0 0	0 0	0 0	0 0
M 4	0 0	0 0	0 0	0 0	0 0	0 0
M 5	0 0	0 0	0 0	0 0	0 0	0 0
M 6	0 0	0 0	0 0	0 0	0 0	0 0
M 7	0 0	0 0	0 0	0 0	0 0	0 0
M 8	0 0	0 0	0 0	0 0	0 0	0 0
M 9	0 0	0 0	0 0	0 0	0 0	0 0
M 10	0 0	0 0	0 0	0 0	0 0	0 0
M 11	0 0	0 0	0 0	0 0	0 0	0 0
M 12	0 0	0 0	0 0	0 0	0 0	0 0
M 13	0 0	0 0	0 0	0 0	0 0	0 0
M 14	0 0	0 0	0 0	0 0	0 0	0 0
M 15	0 0	0 0	0 0	0 0	0 0	0 0
M 16	0 0	0 0	0 0	0 0	0 0	0 0
M 17	0 0	0 0	0 0	0 0	0 0	0 0
M 18	0 0	0 0	0 0	0 0	0 0	0 0
M 19	0 0	0 0	0 0	0 0	0 0	0 0
M 20	0 0	0 0	0 0	0 0	0 0	0 0
S 1	0 0	0 0	0 0	0 0	0 0	0 0
S 2	0 0	0 0	0 0	0 0	0 0	0 0
S 3	0 0	0 0	0 0	0 0	0 0	0 0
S 4	0 0	0 0	0 0	0 0	0 0	0 0
S 5	0 0	0 0	0 0	0 0	0 0	0 0
S 6	0 0	0 0	0 0	0 0	0 0	0 0
S 7	0 0	0 0	0 0	0 0	0 0	0 0
S 8	0 0	0 0	0 0	0 0	0 0	0 0
S 9	0	0	0	0	0	0
S 10 (W5 / W40)	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
S 11	0	0	0	0	0	0
S 12	0 0	0 0	0 0	0 0	0 0	0 0
S 15	0 0	0 0	0 0	0 0	0 0	0 0
S 16	0 0	0 0	0 0	0 0	0 0	0 0
TNBZ 21			0 0			
T 1	0 0	0 0	0 0	0 0	0 0	0 0
T 2	0 0	0 0	0 0	0 0	0 0	0 0
T 3	0 0	0 0	0 0	0 0	0 0	0 0
T 4	0 0	0 0	0 0	0 0	0 0	0 0
T 5	0 0	0 0	0 0	0 0	0 0	0 0
T 6	0 0	0 0	0 0	0 0	0 0	0 0
T 7	0 0	0 0	0 0	0 0	0 0	0 0
T 8	0 0	0 0	0 0	0 0	0 0	0 0
T 9	0 0	0 0	0 0	0 0	0 0	0 0
T 10	0 0	0 0	0 0	0 0	0 0	0 0
TS 1	0 0	0 0	0 0	0 0	0 0	0 0
TS 2	0 0	0 0	0 0	0 0	0 0	0 0
TS 3	0 0	0 0	0 0	0 0	0 0	0 0

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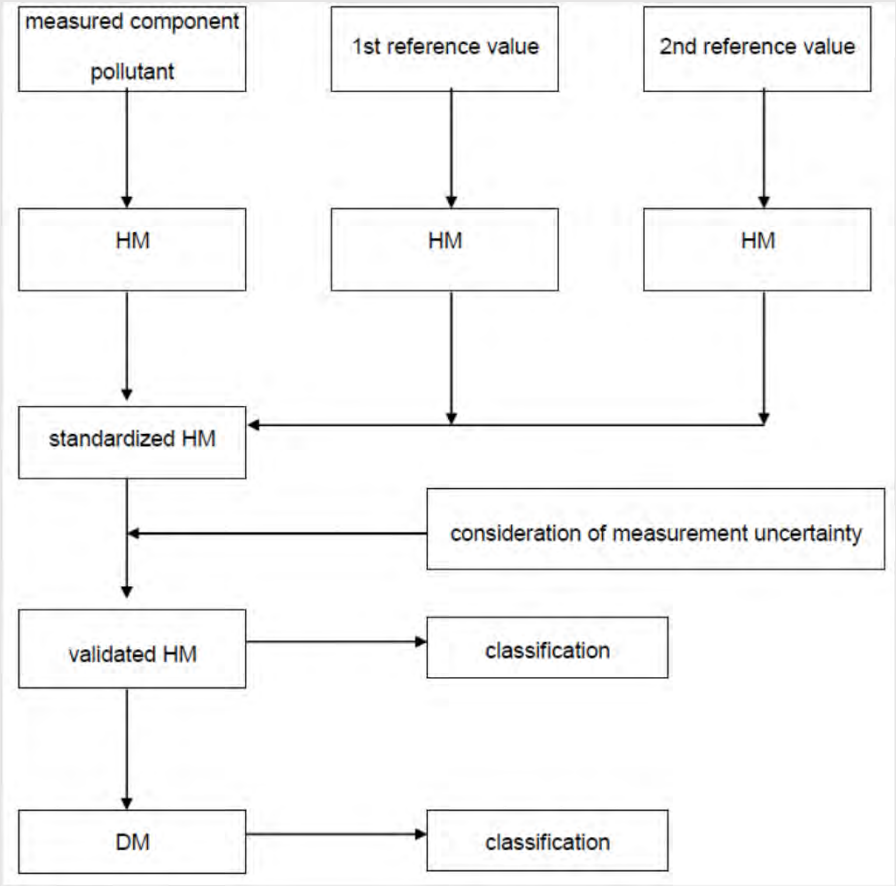
Raw data management

- Raw data is recorded from the AMS
  - Integration time for raw data $\leq$ 5 s
  - The raw data has to be archived
  - Each raw data value is tagged with 3 status signals reflecting
    - Operation conditions of the plant (plant status)
    - Operation conditions of the AMS (data status 1 & 2)

From raw data to standardized and validated mean values

- The raw data value as well as the reference values (temperature, oxygen concentration ,…) are averaged over the desired time range of the applicable short time average e.g. 0,5 h
- The averaged values are used to calculate the *standardized mean value*
- The standard measurement uncertainty (derived from QAL2) is subtracted from the standardized mean value → *validated mean value*
- Long time average values (e. g. daily average) are calculated from the validated mean values

From raw data to standardized and validated mean values



Status Signals for raw data and average values

- Plant status
  1. **G**: plant in operation (monitoring required)
  2. **X**: plant not in operation (no monitoring required)
  3. **W**: plant in maintenance (no monitoring required)
  4. **U**: plant status unclear (???)
- Measured value status 1 (AMS / result related)
  1. **K**: value valid but out of calibration range
  2. **E:** value valid but substitute values were used for standardization
  3. **G:** normal valid value
  4. **S:** AMS defective
  5. **W:** AMS in maintenance
  6. **I:** 2/3 criterion not fulfilled (only average values)
  7. **U**: Unclear AMS error
  8. **N:** Value may not be graded
  9. **X:** No values available

Status Signals for raw data and average values

- Measured value status 2 (plant operation related)
  1. **A**: plant in operation (monitoring required)
  2. **B**: normal operation
  3. **N**: Value may not be graded
  4. **R**: Exhaust gas treatment out of order
  5. **X:** No measured value
- Counter status
  1. **G**: valid value
  2. **X:** invalid value

Examples

- Situation: Plant in normal operation, AMS working properly.
  - Status: G G B
- Situation: Plant in normal operation, AMS working properly but oxygen reference value not available
  - Status: G E B
- The status is stored with each raw data value
- The status associated with the average values is derived from the raw data status

Status: from raw to average value status

- General rule:
  - The average value get the status that was valid for at 2/3 of the integration time. (Independently derived for each status)
  - If no status was present for 2/3 of the integration time the one with the lowest priority is chosen (priority = number on the previous slides)
- Exceptions
  - Most important: If at least one raw value has the status „G“ the average gets always „G“
  - Some more … see SKK

Classes

- Depending on value and status combination each average value is assigned to a class and increases the corresponding counter.
- This list refers to plants according to TA LUFT
- Classes for short term average values:
  - M01-M20: twenty equidistant classes ranging from 0 to 2 · ELV.
  - S1: Limit violation (Shot time average value > 2 · ELV)
  - S2: 2/3 criterion violated: Valid raw data was not available for at least 2/3 of the averaging time
  - S3: Substitute value used for standardization (valid reference values only for less then 2/3 of averaging time available)

Classes

- Classes for short term average values:
  - S4: Due to a malfunction of the AMS valid values are available for less than 2/3 of the averaging time
  - S5: Due to maintenance of the AMS valid values are available for less than 2/3 of the averaging time
  - S6: Plant in operation: Operation-hour counter
  - S7: Due to changes in the mode of operation of the plant values are available for less than 2/3 of the averaging time
  - S8: Values not be graded or implausible
  - S9: Weekly counter (see EN 14181) for values out of calibration range
  - S10: Long term counter (see EN 14181) for values out of calibration range

Classes

- Classes for short term average values:
  - S11: Malfunction of the flue gas cleaning system
  - S14: ELV violation during start-up or shutdown of the plant
- Classes for long-term (daily) averages
  - T1-T10: ten equidistant classes ranging from 0 to ELV.
  - TS1: Counter for ELV violations
  - TS2: No long-term average could be derived – reason: Valid short-term averages for less than 6 hours

QM of data management

- Data management systems (software) are QAL1 certified
- Integrity of data management is checked during AST (VDI 3950)